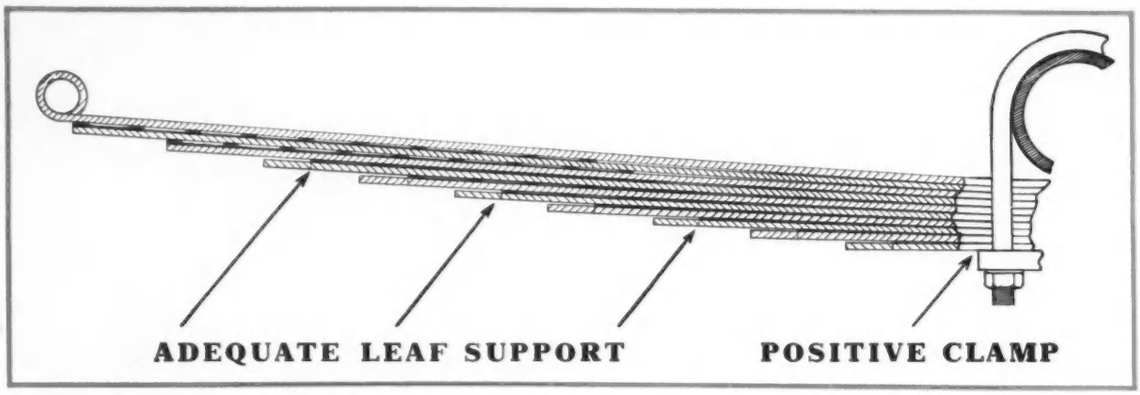
S·A·E JOURNAL

MARCH 1931

Our Design has been Fired at but we still contend its Soundness



THE OUTSTANDING QUESTION asked us by the thousands who saw Watson Rubber Interleaves at the Chicago Automobile Show will undoubtedly be asked by the hundreds of thousands who will see them later.

> "Why don't you run the Interleaves clear through from end to end of each spring leaf and thus provide full and adequate support for each leaf?"

While we fully agree with these questioners as to the necessity for adequate leaf support, we nevertheless believe that adequate support does not necessarily call for the full length support of each leaf. Furthermore, in addition to having adequate support it is our most emphatic belief that rubber should not be placed between the leaves of a spring at the section where the spring as a whole must be clamped to the car axle. Even a paper-thin film of rubber between each pair of leaves, when multiplied by eight, would amount to a thirty-second of an inch or so of float or "jelly" to interfere with firmness and certainty of clamp. Possibly such a mere film might be punctured in occasional cases where high spots on adjacent leaf surfaces might happen to coincide. We however have preferred not to rely upon coincidence for our firmness, but to make ***certain*** of it by keeping the rubber definitely ***away*** from the clamped sections.

Adequate leaf support—YES. ALSO however, and equally as important, is the matter of firmness of clamp between springs and axles. We firmly believe that without such combination the whole idea of Rubber Interleaves would be doomed.

In fact, so vitally important do we regard this combination of adequacy of leaf support, yet making it impossible for the rubber to interfere with the firm clamping of the leaves to the axle, that we have covered this very combination in our patent claims.

If the thousands and maybe hundreds of thousands of critics of our present design will look back over the history of Watson products, which at first may have been thought radical in design, but which made good, they will feel some assurance that in spite of their present beliefs, or rather disbeliefs, they may safely count upon this latest Watson product to serve them correctly.

Have a set of these new Watson Interleaves installed in your springs and you will instantly experience what we regard as the greatest advance which has ever been made in the interest of smooth riding comfort.

JOHN WARREN WATSON COMPANY
PHILADELPHIA, PA.

PRESIDENT

S·A·E· JOURNAL

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The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

ON THE AIRWAYS TO-DAY

Guaranteed Forgings

– as on the highways for the last 30 years –

WYMAN-GORDON WORCESTER, MASS. AND HARVEY, ILL.

Vol. XXVIII Nº 3 March. 1931

S·A·E· JOURNAL

Published by the Society of Automotive Engineers, Inc.

Three National Spring Meetings

First Is 19th Aeronautic in Detroit in April, then Production in May and Summer Meeting in June

THE DECISION of the Show Committee of the Aeronautical Chamber of Commerce of America to hold but one major aircraft show in the United States in 1931, and to locate that show in Detroit in the month of April, has provided the locale and time for the 19th National Aeronautic Meeting of the Society. This meeting will be held at the Book-Cadillac Hotel on April 15 and 16.

Careful consideration of the program by the Aircraft and Aircraft-Engine Committees has resulted in provision for six technical sessions, followed by a dinner on Thursday, April 16.

Three sessions will be devoted to aircraft engines, with the following papers: Superchargers, by Oscar Shey; Bearing-Load Analysis and Permissible Loads as Affected by Lubrication, by F. L. Prescott and R. B. Poole; Design and Development of Aircraft Spark-Plugs, by G. M. Paulson; High-Temperature Liquid-Cooled Engines, by Arthur Nutt; Multi-Motored Low-Powered Light Engines, by a representative of the Continental Aircraft Engine Co.; and three cooperative papers on the Knock Rating of Aviation Gasolines.

The last three papers, to which one session is to be devoted, will coordinate the work of several laboratories that are at present engaged in testing and rating, according to their own methods, gasoline made to five different specifications. At the same time, flight tests are being made with the same series of gasolines, and their characteristics and ratings are being checked. This material will then be coordinated into three papers to be presented together with further data on the method of testing and rating.

Three Sessions on Aircraft Problems

One of the three sessions devoted to aircraft problems will be confined to amphibian hulls and float construction, data on which are to be presented in papers by Igor Sikorsky, on A Novel Method of Studying Flying-Boat Hull Models, and by B. C. Boulton, on Some Aspects of Float Construction.

C. J. Cleary, of the Air Corps, Wright Field, will present at a second Aircraft Session a paper on Some Physical Considerations of Textile Materials in Aeronautics. The second paper of this session, in which considerable interest has been evinced, will be on Protective Coatings for Corrosion Prevention, by Lessiter Milburn, of the Glenn L. Martin Co.

Flight Testing is the subject of a paper to be given by E. W. Rounds, of the Bureau of Aeronautics, U. S. N. This will provide a considerable quantity of interesting data obtained in this work in the Navy.

Present indications are that the joint dinner of the Society and the Aeronautical Chamber of Commerce will be one of the most notable aircraft banquets ever staged. While no definite announcement can be made at this time as to the principal speaker, it is no secret that the evening's humor will be furnished by the well-known "Senator" Ford.

As heretofore, the cooperation of the Detroit Section will be had on the dinner arrangements.

Summer Meeting in June at White Sulphur Springs

FIVE Summer Meetings of the Society have been held since one was staged at White Sulphur Springs; and, at every one of them, many members have been heard to say: "I like this place, but in my opinion nothing equals White Sulphur."

The members who have expressed this opinion will be glad to know that the 1931 Summer Meeting will be held at White Sulphur Springs, June 15 to 19, and those who have heard it expressed will undoubtedly be glad to have an opportunity to verify it by personal experience.

Present indications point to a large attendance at the Summer Meeting, and all the soothsayers who have been consulted to date on the subject predict that everyone who attends the

(*Concluded on p.* 399)

Meetings Calendar

National Meetings of the Society

19th National Aeronautic Meeting—April 15 and 16
Book-Cadillac Hotel, Detroit

Production Meeting—May
Milwaukee; Sponsored by the Milwaukee Section

Summer Meeting—June 15 to 19
White Sulphur Springs, W. Va.

20th National Aeronautic Meeting—Sept. 1 to 3
Hotel Statler, Cleveland
In Conjunction with National Air Races

March Section Meetings

Buffalo—March 3
Hotel Statler
History of the Internal-Combustion Engine—P. M. Heldt, Engineering Editor, *Automotive Industries*

Baltimore—March 19
Lord Baltimore Hotel; Dinner 6:30 P. M.
Diesel Engines for Automotive Use—C. L. Cummins, Cummins Engine Co.

Canadian—March 18
Royal York Hotel, Toronto
Past, Present and Future of the Diesel Engine—C. F. Kettering, General Motors Corp.

Chicago—March 3
Hotel Sherman
Transportation Meeting

Cleveland—March 9
Hotel Statler; Dinner 6:30 P. M.; Entertainment
New Engineering Features in 1931 Cars—Harold F. Blanchard, Technical Editor, *Motor*

Dayton—March
Recent Development in Parachutes—Major E. L. Hoffman, Engineering Division, War Department

Detroit—March 3
General Motors Research Auditorium; 8:00 P. M.
Joint Meeting of Student and Junior Members

Detroit—March 16
Book Cadillac Hotel—Ladies' Night

Indiana—March 12
Hotel Severin, Indianapolis
Subject: Riding Comfort

Metropolitan—March 26
A.W.A. Clubhouse, 357 West 57th Street, New York City; Dinner 6:30 P. M.
The Development and Design of the Marmon-16 Engine—Howard E. Marmon, Vice-President in charge of Engineering, Marmon Motor Car Co., and George H. Freers, Chief Engineer, Marmon Motor Car Co.

Milwaukee—March 4
Milwaukee Athletic Club; Dinner 6:30 P. M.
Electric-Furnace Alloy Irons, Their Special Advantages and Uses—A. R. Janes, President and General Manager, Standard Foundry Co.

New England—March 11
Walker Memorial Building, M.I.T.; Dinner 6:45 P. M.
Diesel Engines for Automobile and Airplane Service—Prof. Myron S. Huckle, Massachusetts Institute of Technology

Northern California—March 16
University of California, Berkeley, Calif.
Traffic Safety—V. W. Killick, Division of Motor Vehicles, Department of Public Works of California

Northwest—March 11
New Washington Hotel, Seattle, Wash.
Grinding Wheels—A. W. Cox, The Norton Co.

Oregon—March 12
Multnomah Hotel, Portland; Dinner 6:30 P. M.; Entertainment
Engine-Cylinder Reconditioning—C. H. Stokke

Philadelphia—March 11
Philadelphia Automobile Trade Association; Dinner 6:30 P. M.
Performance Characteristics of Storage Batteries in Modern Cars—L. E. Lighton, Electric Storage Battery Co.

Pittsburgh—No Meeting

Southern California—March 7
Alexandria Hotel, Los Angeles—Annual Dinner-Dance

St. Louis—March 25
Engineers Club, 4359 Lindell Boulevard.
Motor Lubrication—C. M. Larson, Sinclair Refining Co.

Syracuse—March 10
Hotel Syracuse
Diesel-Engine Developments—Harte Cooke, Chief Engineer, McIntosh & Seymour Corp.

Washington—March 19
Washington Hotel; Dinner 6:30 P. M.

Wichita—March 23
Green Parrot Inn
N.A.C.A. Cowling with Variations—R. R. Higginbotham, Project Engineer, Stearman Aircraft Co., and Herbert Rawdon, Chief Engineer, Travel Air, Curtiss-Wright Airplane Co.

Practical Streamlining of Cars

Metropolitan Section Members Consider How Results of Wind-Tunnel Tests Can Be Applied to Win Public Acceptance

METROPOLITAN Section's February session on Theory and Practice in Streamlining Automobiles resolved itself into a discussion of the extent to which it will be possible to reconcile streamlining with beauty as the public now conceives it. While the actual test figures presented to prove the technical value of streamlines in miles per gallon and miles per hour went unchallenged, it was evident that doubt exists that there are advantages which can overcome objection to the unconventional appearance of true streamline automobile designs.

More than 100 members and guests who attended the meeting were surprised to find themselves dining in a French atmosphere contributed by extensive mural scenics remaining from the Brittany Ball held 24 hr. earlier in the same room of the A. W. A. Building. Following announcements of meetings scheduled for March 26, on Six-teen-Cylinder Engine Design, and April 9, on Aviation, a Section Nominating Committee consisting of A. C. Bergmann, Joseph A. Anglada, F. H. Dutcher, J. J. Percivall and Herbert Chase was elected. A message of regret from Capt. Malcolm Campbell for his inability to attend and tell about his Blue Bird record-breaking car was read by Chairman Wolf, who then introduced as the first speaker Julio Andrade, assistant chief designer of the Murray Corp. of America.

Mr. Andrade pointed out that air-resistance tests made up to this time in the United States have been for scientific research without any intention or expectation of applying the findings to improve any particular car. European work along these lines, he said, has gone to the other extreme of designing a car with true streamlines so radically different from the conventional shapes that they could never be sold. "It seems to me," said Mr. Andrade, "that neither extreme is ideal or necessary, but that an approach to perfect streamlining can be sought and obtained, not only for better utilization of the engine power and for the better handling of the car at great speeds, but also as an excuse to introduce novel shapes and provide a larger field for the designer."

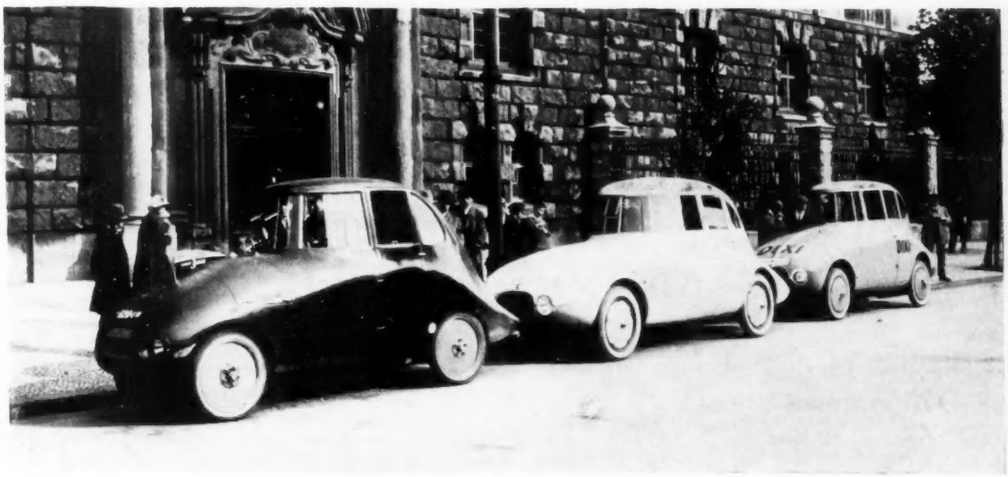
He went on to tell of his creation and wind-tunnel testing of original three-dimensional models for which no drawings to specify the development of surfaces were made in advance. Methods used to obtain true reproduction of road conditions with models were detailed in word and picture. A wind-tunnel comparison of the Flying Cloud and the Reo Royale designs indicated that the latter required 7½ less horsepower than the former to overcome air resistance at 80 m.p.h. Flow-pattern tests were also explained and illustrated.

Mr. Andrade mentioned many factors to be considered and told the advantages and disadvantages of certain features of streamline design. He advocated covering the under chassis and giving special attention to rear decks, front fenders and ventilators. It must be remembered, too, that beauty disguised in usefulness is more attractive than beauty by itself, he said, adding: "To obtain perfect streamlines or even a near approach to perfection seems to me impossible, for, if this has not been done with the airplane, what hopes are there for the automobile, to which air resistance will never be as important a factor? We must, therefore, enter this field with the idea only of reducing what we regard as unnecessary air resistance, keeping in mind that our product must be sold to persons of diversified taste to whom the looks of the car is at least as important as its physical merits."

Some European Streamlined Cars

The next speaker, Othmar K. Marti, chief engineer of the American Brown Boveri Co., told about the work of Paul Jaray, who was one of the early designers of airplanes and dirigibles in Austria and Germany and with whom Dr. Wolfgang Klemperer, chief engineer of the Goodyear Zeppelin Corporation, was for some years associated. Illness prevented Dr. Klemperer's attendance at the meeting.

While wind-tunnel tests were made both in Friedrichshafen and at New York University on streamlined models, the building and testing of full-size completely streamlined cars was emphasized by Mr. Marti as equally important. Pictures of these cars were shown and the speaker gave details of road tests made in October, 1928, near Zurich, Switzerland. In the tests a



EUROPEAN STREAMLINE CARS—THE LEY, AUDI AND DIXI

standard Chrysler-72 was compared with another Chrysler-72 carrying a streamlined body for coasting ability, acceleration and fuel consumption, and in each case the streamlined car demonstrated marked superiority. Other advantages were found, said Mr. Marti, in improved ventilation, decreased vibration, increased floor space, greater safety and improved visibility.

Pictures of Captain Campbell's racer were shown and general discussion followed. Past-President Edward P. Warner stated that the many protuberances on an automobile prevent real streamlines and disturb the air-flow beyond any possibility of again smoothing it out.

Prof. Alexander Klemin, of New York University, commended the test methods used by Mr. Andrade but suggested that a flat board placed across the top of a wind-tunnel model and extending to the front and rear gives a more exact reproduction of road conditions than does the duplicate chassis placed as a reflection of the test model. Professor Klemin said that smoke is a much better medium for the study of air patterns than is a mixture of kerosene and lamp-black. Buffeting from air eddies is a vital factor in vibration, he added.

D. H. Montgomery, chief engineer of the New Britain Gridley Machine Co., showed pictures of a car he designed to follow airfoil lines, with the engine at the rear. He discussed his design at some length.

The next meeting of the Metropolitan Section will be held Thursday, March 26, at the A. W. A. Clubhouse, New York City. A paper on 16-cylinder engine design will be presented by Howard Marmon, winner of the Metropoliton Section medal for passenger-car development, and George H. Freers, chief engineer of the Marmon Motor Car Co.

Syracusans Discuss Air-Cooled Engine Development

IN spite of bad weather, 42 men interested in automotive research assembled in the Hotel Syracuse at the Feb. 3 meeting of the Syracuse Section. Carl T. Doman, research engineer of the H. H. Franklin Mfg. Co., presented an interesting paper on Air-Cooled-Cylinder Development. (See S.A.E. JOURNAL, February, 1931, p. 177.)

The problems which confronted early engineers in this field were reviewed and illustrated by lantern slides. Step-by-step experiments that resulted in the present practice in air-cooled-engine design were discussed. Mr. Doman pointed out that this type of engine should properly be known as "exclusively air-cooled," since all engines are air-cooled, although most of those in present use dissipate the heat first to water.

Among the advantages of the air-cooled engine which Mr. Doman mentioned are its freedom from plumbing troubles; its economy, resulting from quick warming and consequent saving of fuel; and its adaptability to a more flexible type of chassis construction, since it is unnecessary to protect a radiator from road shock and torque.

The present air-cooled engine weighs slightly more than a water-cooled engine of equivalent power taken separately; but less weight per horsepower is the invariable result when the weight of the radiator and the fluid in the cooling system is considered. Lightness of the air-cooled engine, together with the factor of reliability, is responsible for its popularity in aviation use. Army test records show, Mr. Doman said, that 75 per cent of the troubles with water-cooled engines were directly traceable to the cooling system. The Army now has, besides its aviation equipment, seven tanks equipped with air-cooled engines. These engines have brought the speed of the tanks to double that obtained with the former equipment and at the same time the fuel consumption has been reduced by 50 per cent.

Development Left to One Company

Nearly one-half of the persons present at the meeting entered into the discussion following presentation of the paper and considerable interest was aroused. In answer to a question, Mr. Doman stated that there is no reason why air-cooling cannot be applied to an engine of any number of cylinders or of any type of block construction. That this has not yet been done he ascribed to the fact that the development of the air-cooled engine has been achieved mainly by one company's research, while the rest of the industry had been free to pioneer more advanced forms of the conventional type of engine. The expense of research and changing over to a new type was cited as a reason for the lack of interest shown by most manufacturers in the air-cooled type. Failure of the preliminary attempts of several companies to construct a satisfactory air-cooled engine acted as a further deterrent.

In this connection one member stated that the successful manufacturer is the last to seek radical changes in design. As long as a car model or an engine is giving good results, there is no need to change; but a company that has been losing ground is likely to go to extremes to get away from old troubles and awaken new consumer interest. This member expressed fear that some such companies might now seize upon the air-cooled engine to attempt a "comeback" and that, in the event of failure, this would give the public a bad impression of the value of this type of automobile engine.

Essentials for Cold Starting

Dr. Becker Gives New England Section Information Gained from Two Years' Tests

MORE THAN 150 members and guests attended the Feb. 10 meeting of the New England Section at the Hotel Kenmore, Boston, and they heard some interesting facts about the effect of cold weather on motor-vehicles. A dinner preceding the business meeting was attended by 42 members, at which Dr. A. E. Becker, speaker at the meeting, was the guest of Chairman Albert Lodge and the other officers of the Section.

As a prelude to the address, the Chairman asked for names for a Nominating Committee to bring in a list of officers of the Section for the year 1932 to be voted on at the final meeting this season. Those named were M. F. Wolfard, Frank E. H. Johnson, W. H. Clark, J. B. Moyer and Glenn S. Whitham, all ex-chairmen.

Dr. Becker, of the Standard Oil Development Co., was then introduced and the members got a great deal of information regarding cold-weather starting and lubrication. This was particularly true after he had finished his paper, when he answered many questions. Even when the question period ended he discussed various angles of the fuel and lubricating-oil question for some time with a large group who remained for the purpose. Some of the questions asked him referred to hydrogenation, but he explained that this subject does not come in his department. He did, however, explain what was sought by this process.

Why Cold Starting Is Difficult

The purpose of the paper, said Dr. Becker, was to point out some of the reasons why skill is required in starting an internal-combustion engine in cold weather and to suggest practical methods for overcoming or eliminating the difficulties. No more difficulty would be encountered in starting at low temperature than at summer temperature, he said, if a choice of suitable fuel and lubricant were made were it not for the fact that very soon after the engine is started both the fuel and the oil must function under operating temperatures similar to those prevailing in the engine in warm

weather. This is particularly true as regards lubrication of the cylinder-walls. For this reason, fuels and lubricants must be selected that represent a working compromise.

To enable the engine to continue running without resorting to the starter again after the first firing of the charge, a winter gasoline of good volatility should be selected. Some tendency has existed, however, to overestimate the importance of this factor, according to Dr. Becker, and it was to this phase that the paper was chiefly devoted.

Details were given of a series of dynamometer tests, made in the latter part of 1928 in a cold room, to determine (*a*) the initial breakaway torque, (*b*) several secondary breakaway torques taken at 4-min. intervals and (*c*) the motoring torques and speeds up to 150 r.p.m. on a fixed time-schedule. About 30 lubricants were tested in each of three engines, and Dr. Becker showed charts of the results obtained. From the data secured the deduction was drawn that a partial answer to the starting problem is to use lubricating oils of very low viscosity or to accomplish the same result by either prediluting oils of higher viscosity or permitting the latter to become diluted rapidly in service.

Starting Viscosity Very Important

But, as diluted oils are undesirable after the engine is warmed up, the problem was attacked from a different angle in a series of starting tests conducted during the last two years with about 30 cars and trucks of various makes. These tests were made in the cold room, where the temperature could be controlled and held constant. Volatility of the fuel was found not to be the determining factor in cold starting. There was a tremendous difference in the starting ability of the different cars, one car, for example, starting on crankcase oil of as much as 80,000 Saybolt-sec. viscosity whereas trouble would be encountered with other cars with oil of 25,000-sec. viscosity at the same temperature.

The tests showed that pour-point and viscosity are equally important in establishing lubrication of a cold engine. Consideration of the time required to establish flow with the various oils tested, and of the quantities of oil delivered when the flow is established, also leads to the conclusion that the trend toward thermostatic control of the crankcase-oil temperature is decidedly in the right direction. It is as important, said Dr. Becker, to raise the oil to operating temperature soon after the engine is started as it is to cool it under severe operating conditions.

The real controlling factor is the relation of friction horsepower to starter horsepower and engine power at low speeds. Hence the manufacturer should design the engine and starting equipment so that, as soon as firing occurs, the power developed will be sufficient, not only to kick out the starter, but to maintain operation and rapidly accelerate the engine.

Viscosity of the oil at the starting temperature is of great importance; it must be low enough to enable the engine to carry the friction load as soon as it fires. An oil that will give good starting results in one car may be entirely unsuited for another car under the same winter temperatures.

The most adverse starting conditions are encountered immediately after charging the engine with fresh oil. After several days' operation, the oil becomes sufficiently diluted to considerably reduce the starting effort required. Therefore it is advisable to change the oil on warm days. After starting a cold engine, it should be idled until lubrication is fully established, as otherwise the cylinder-walls and bearings may be scored.

Low pour-point oils do not always establish lubrication more quickly than high pour-point oils; viscosity at the crankcase temperatures is as important, according to the speaker, as is the pour-point.

If more attention were given by the operator to making sure that the starter, battery, ignition system and spark-plugs were in good condition and the gap settings and carbureter adjustment correct, less starting trouble would be encountered in cold weather.

Photographs at 400 Miles

Record Dayton Section Meeting Sees Marvelous Pictures Made on South American Flight

DAYTON'S great interest in aeronautics was reflected at the record meeting of the Dayton Section of the Society at the Engineers Club on the evening of Feb. 10, when more than 400 persons gathered to hear an address by Capt. Albert W. Stevens, of Wright Field, on the National Geographic Society's 10,000-mile exploration flight from the City of Washington to Buenos Aires, Argentina. Twenty-eight members of the Section attended the dinner that preceded the technical session. Most of the time of the session was occupied in showing a most interesting collection of slides of photographs taken on the trip.

The flight was by way of Cuba, the Antilles, Trinidad, and down the east coast of South America to Rio de Janeiro and Buenos Aires, thence over the Andes Mountains to Chile and up the west coast. Captain Stevens briefly described the meteorological and climatic conditions of South America and the effect they produce, from glaciers and icebergs at the south end of the continent, to desert regions in northern Chile and tropical jungles near the equator where the rainfall averages 1 in. per day.

Airline Service Quick and Safe

Regarding air-mail and passenger service, the speaker said:

Down both the east and west coasts there is an airline. The air-mail route is principally down the west coast. This route saves one or two days, because it is almost a straight line from New York City to Santiago, Chile. The flying is perfectly safe. All planes of the Pan-American Airways are equipped with radio, so a ship is in constant communication with the station it has just left, with the station just ahead and with other airplanes of the same line which are in the air at the time. The use of radio in airplanes is a great factor toward ensuring safety. In a remote case of the plane being forced down, the radio helps. Being forced down very seldom happens, however, because the engines are very reliable and are not worked up to capacity; running them at reduced capacity increases their service life. These engines are overhauled every few hundred hours. If weather conditions are bad, the pilots do not fly. The ship we flew in had a wing-spread of 106 ft. and could hold 22 passengers.

Flying does not cost a great deal more than other means of travel, considering the time saved and the greater opportunities to see more sights. To go by steamer to Buenos Aires costs $450. It costs about twice as much to go by airplane. However, the trip by plane can be made in one-third the time required by steamer, and 20 times as many interesting sights can be seen.

Color Plates and Filters Used

Among the photographs shown were some that were taken at a distance of nearly 400 miles. These were taken through red filters which it was almost impossible to see through with the eye but allowed the blue rays to pass, so that an exposure of only 1/20 sec. was sufficient. Pictures taken of the level pampas distinctly showed the curvature of the horizon, which amounted to 1/32 in. on a 9-in. plate.

In a short discussion following the slides, Captain Stevens explained how the pictures were taken. When flying over mountains, he said, if on the lee side the plane would be dragged down by wind currents. On the windward side there is always an up current, hence most of the pictures were taken from that side, as the wind currents helped in gaining altitude. The wind pressure and air currents are caused by differences in temperature, and these make very rough flying.

Captain Stevens then explained the special plates and filters used in mak-

ing the pictures. One side of the plate is dusted with starch grains and on the back of the glass a coating of emulsion is applied. The latter is called a panchromatic film. The glass side is placed toward the lens. This plate is very sensitive to all colors, whereas the ordinary plate is sensitive only to blue. A deep-red filter is used over the plate. This is so dense that, when looking through it with the naked eye, objects cannot be distinguished. This filter enables the photographs to be taken in the correct colors, thereby appearing much more realistic. Filters are made up of blue, yellow and red grains to shut out the different primary colors. A new process called the Findley-plate process uses a screen for dividing the colors. For aerial photography, however, the panchromatic films are best because more contrast is obtained. A film that is very sensitive to red is desirable. In taking pictures from great altitude, a blue filter is put over the lens to cut out the blue light of the sky. In taking extremely distant pictures, the red filter is used. The latter is not suitable for other pictures, because it makes them too harsh and contrasting.

Robe, Not Williams, Designed Two-Cycle Engine

INADVERTENTLY the designer of the two-cycle engine with direct fuel-injection, which was described at the December meeting of the Baltimore Section, was given in the report printed in the January issue of the S.A.E. JOURNAL as E. W. H. Williams. The experiments with fuel injection in this type of engine were carried out by Walter B. Robe, a consulting automotive engineer of Baltimore, who presented the paper describing his work at the Section meeting. This error occurred in the office of THE JOURNAL through a misunderstanding of the report of the meeting, and apologies are offered to Mr. Robe. The paper covering this interesting deve'opment was published in full, with illustrations, in *Automotive Daily News* for Dec. 17, 1930.

Milwaukee Section Members Go Free-Wheeling

FREE-WHEELING was the topic of the evening at the first meeting of the new year for the Milwaukee Section, held on Feb. 4 at the Milwaukee Athletic Club, preceded by the usual dinner and entertainment.

The attendance at the dinner was over 60, and others who came in for the technical session swelled the total to about 125.

As the paper was given by H. E. Churchill, of the Studebaker Corp. research department, Milwaukee's Studebaker distributor kept open house and demonstrated free-wheeling all afternoon to the members of the Section who accepted his hospitality.

Before the dinner was finished it was easy to see that free-wheeling was bound to be popular with the crowd. The Entertainment Committee had done its usual good work and, although the male quartet was rated highly, most interest centered around the free and frequent wheeling of the dancing team.

A short business meeting followed the dinner, when Chairman Frantz introduced Mr. Warner, General Manager of the Society. Since he was the guest of honor, by a happy coincidence he also drew the attendance prize, an electric clock.

Free-Wheeling of Ancient Origin

Acting as Chairman, Mr. Warner introduced the speaker of the evening, who presented a number of the outstanding features of free-wheeling, none, however, affording greater amusement than the statement that the free-wheeling principle originated with Noah when he invented a drive for his primitive lathe by attaching an oxtail rope to a bent twig. The paper was a scholarly presentation of the many steps in preparing this novel departure in motoring.

The discussion brought out a number of interesting points with respect to the effect that free-wheeling is bound to have on other features of the car. With a car rolling freely with all the engine noises diminished, due to the engine idling, the demand for quietness in other parts is going to be considerably increased, and improvements in bodies, springs, frames and all other elements are bound to result.

Following the free-wheeling session, Chairman Frantz announced the plans for a National Production Meeting to be held by the Society in collaboration with the Milwaukee Section. This meeting is to be scheduled for the first Wednesday in May, and many Section representatives of the large manufacturers have offered their personal assistance to make the Production Meeting a success.

Adjournment was unusually late, largely because of interest in the discussion of Mr. Churchill's able paper.

Carboloy and Highways Discussed

Northwest Section Hears About New Cutting Material and State Road Progress

THE dual-topic method again prevailed at the Northwest Section meeting held in Seattle on Feb. 6, as has been true of several recent meetings. Highways and Carboloy were the topics presented. They seem far apart and yet they come together, to some extent, in the modern motor-car, the latter as applied in production and service; the former as applied in use. George H. Shearer, district engineer of the Washington State Highway Department, gave a résumé of the State program, something on construction costs and specifications and big projects under way or planned for the near future.

R. B. Lane, with the General Electric Co., spoke on Carboloy, sketching the development of this material since it was first put on the market in 1928, following two years of experimentation in the General Electric Co. laboratories. What Carboloy tools will do in high-speed machining, thus speeding up production and the consequent economy in the long run in certain operations, comprised the main portion of the talk.

Don F. Gilmore, who presided, appointed a Nominating Committee which will soon report. This consists of R. S. Taylor, W. R. Coleman, Reece Lloyd, R. P. Dennison and A. W. Oberg. Chairman Gilmore announced that the next meeting will be on March 11, when John A. C. Warner, Secretary-Manager of the Society, will visit the Section. The technical portion of the program is to be devoted to machining steel and other metals.

Carboloy Possibilities and Limitations

Carboloy used in cutting-tools is not tempered, explained Mr. Lane, so it runs as well at red heat as when cold. This permits increased speed of cutting. Machining glass, turning Hadfield's manganese steel, and other "stunts" show to what uses the material may be put. The machining of hard rubber shows that the edge on a Carboloy tool is not lost. The same is true of Bakelite turning. In one operation in the General Electric plant, ordinary high-speed tools required refinishing after turning out 150 units, whereas Carboloy turned out 11,000 in this instance, with the tool still good. Good results on aluminum products; cast iron, where the surface is hard, uneven, and often sandy and difficult; and on chromium-nickel steel are obtained with the material, with little or no distress at all to the tool, asserted the speaker. Limitations include a tendency to break, due to high brittleness, and the cost is high. Introduction of Carboloy, Mr. Lane declared, is the first important step for-

ward in tool-materials since Taylor and White brought out high-speed tools.

Washington State Highway System

Charles Finn, Treasurer of the Northwest Section and an expert on highways, presented Mr. Shearer, whose talk was very interesting, though not of a technical nature. Both pointed out the relation and the importance of highways to the car.

The Washington State highway system consists of 3268 miles, exclusive of 241 miles located within cities. In addition to these State roads, the main highway system includes 44,000 miles of county roads. On the 241 miles within city limits, the State pays $500 per mile to the municipalities for maintenance.

The new era in road building, declared Mr. Shearer, came in 1917, when the system was mapped out definitely instead of building isolated and disconnected roads here and there. To date $128,200,000 has been spent on the State highway system, and also $23,000,000 of State funds on county and lateral systems. A high standard of construction prevails, based on specifications of the Federal Government.

Lively discussion followed Mr. Shearer's talk. It developed that maximum curves on Class-A State roads, such as the Pacific Highway, are 5 deg., and the maximum grade is 5 per cent, except on the new Snoqualmie Highway, where it is 5.8 per cent. This pass, Mr. Shearer thinks, can easily be kept free of snow because of the new and wider highway completed last summer. Often the snowfall there amounts to 40 ft. in a season, but the last three years averaged only around 20 ft. The snow is a heavy and varying type, hence manufacturers of snowplow equipment have often come to grief on the Snoqualmie road, he said. Two rotary plows are used, following high-speed push plows. The main problem is to throw the snow away from the edges so that it will not pile up too deeply. This avoids narrow driveway and wetness on the margins of the road when the snow melts, which would make the roadbed soft and dangerous, he continued.

A traffic count shows 300 cars passing over the highway daily, with 1100 coming up from the west over the week-end for snow sports at the summit. The cost to keep the road open, said Mr. Shearer, has been moderate.

Following the address, the Washington Loop Highway, made possible by completion of Stevens pass; the Lake Union or Aurora bridge in Seattle, oiling of the roads, upkeep costs, load-weight limitations on trucks, self-elimination of solid-tired trucks without legislating, and other angles of the highway subject were discussed.

New-Model Advances Reviewed

Roos Tells Indiana Section of Evidences of Greater Independence of Thought

D. G. ROOS, chief engineer of the Studebaker Corp., addressing the Indiana Section on Thursday evening, Feb. 12, brought his paper to a close with the statement that he feels that "free-wheeling is but a step in the direction of automatic or variable-speed gearless transmissions, which are now being developed in Europe, as in these some sort of free-wheeling is the invariable rule. Therefore, since some of these gearless transmissions are near to commercial use, all the free-wheeling interest and use is leading us to further development in the way of even less cumbersome transmissions."

While Mr. Roos's paper was a Review of the 1931 Automobile Shows, in which he covered the entire field of recent motor-car development in a splendid analysis and left to the end the subject of free-wheeling, this last was not the least important part of his general review.

The significant feature of the year's shows, Mr. Roos believes, was the evidence on every hand that management has turned to the engineers to give the companies products that will stimulate potential-buyer interest in this period of diffident buying. "At both the New York and Chicago shows,"

(*Continued on p.* 393)

JANUARY MEETING OF THE NORTHWEST SECTION AT THE NEW WASHINGTON HOTEL, SEATTLE

Chronicle and Comment

Conflicting Reports on Diesels

Captain Cole and his crew organized a Diesel engine session in Cleveland last month that resulted in a well-ordered battle from which issued a thousand and one ideas and reports, for and against Diesel engines. George W. Smith, Jr., Vice-President of the White Motor Co., who acted as sponsor for the session, very deftly engineered one of the most profitable discussions of any controversial subject that has recently been staged.

To the interested observer, gathering his conclusions from this meeting,

It Might Seem

That fuel economies provide no legitimate incentive for developing the Diesel type of engine; the price differential between gasoline and fuel oil will vanish when the demand for fuel oil increases. . . . That with *no* differential existing between light and heavy fuels, possible savings in fuel cost for a given output fully justify the development of Diesel engines for automotive use.

That Diesels are very sensitive as to fuel requirements and that a narrow range of fuel specifications must apply in the preparation of fuel for a given engine type. . . . That Diesels will accept and digest without complaint almost anything from alcohol to asphalt.

That Diesels are particularly well adapted to marine and aircraft use because the heavier fuels eliminate fire hazards. . . . That fuel oil for aircraft and marine Diesels is difficult to handle properly to prevent creeping which results in the promotion of burning of parts that are covered by it.

That Diesel engined aircraft may deny the pilot the privilege of landing whenever piston leakage allows oil to be pumped from the crankcase and burn in the cylinders; the pilot in this dilemma must remain in the air until his crankcase is drained. . . . That this condition can easily be remedied and that no difficulty from this cause need ever exist.

That Diesels are bad smokers, the smoke having a very disagreeable, acrid odor. . . . That Diesels, properly operated, smoke less than conventional gasoline engines and the exhaust is sweet and clean.

That valves, jets and pumps on Diesels are, and are inherently, sources of continual trouble and need frequent attention. . . . That these elements are operating, day in and day out, without attention for thousands of hours and need no more nursing than a set of spark-plugs.

That Diesels must of necessity cost more to build. . . . That Diesels in quantity production will cost practically no more than the conventional engine to build.

That Diesels must be much heavier for a given rating. . . . That Diesels for a given rating are no heavier.

That present automotive Diesels have all the desirable performance characteristics of gasoline engines and some in addition. . . . That present automotive Diesels lack flexibility and do not perform properly over a desirable speed and load range.

That Diesel development, as now in progress, is up the wrong track and cannot possibly result advantageously. . . . That present-day development of Diesels has a clear course ahead and that the final result will be a happy blending of features that now characterize the Diesel and conventional gasoline engine.

THAT automotive "Diesels" are not Diesels at all; there is no such thing today in operation as a real automotive Diesel engine.

Quoting from page 78 of the hymnal, "We shall know each other better when the mists have cleared away."

Pullman Fact Number Six

To quote from an interesting leaflet, one of a series of twelve, now being distributed by the Pullman Co.:

> In order that they may be satisfied, the heating and ventilating systems are most carefully coordinated; scientific apparatus and multiple controls enable the individual passenger to indulge his own preference; and the result is a triumph in practical sanitation.

Those who travel frequently in Pullman cars may regard this statement with certain reservations. For those who wish to draw parallels, however, an objective is here offered for those automotive engineers to whom passenger comfort is of paramount importance.

In various discussions among Society members, attention has been called to the fact that heating, cooling and ventilation of the *engine* have for years received the most careful consideration of the most able engineers, but, in general, the *passenger* has been allowed to journey in the midst of whatever temperature and air conditions may happen to prevail.

In view of the undisputed fact that passenger comfort is of primary importance, there exists a very large incentive for the adoption of adequate means for air conditioning, both in private cars and in buses. It is to be hoped that commendable advances along these lines will be forthcoming in the near future.

Production Meeting for Milwaukee

Under the leadership of Chairman Frantz, every member of the Milwaukee Section is lending active support to the National Production Meeting that will be held in Milwaukee early in May under the joint sponsorship of Vice-President Brumbaugh's Production Activity Committee and the Milwaukee Section.

Joseph Geschelin, Chairman of the Meetings Committee of the Production Activity, and Chester Ricker, Chairman of the Milwaukee Section's Meetings Committee, promise an array of real production addresses by real production men. Several very interesting plant inspections will be included in the program which will undoubtedly attract a large number of producers from the automotive and allied industries.

Action in Canada

A more progressive spirit than that existing in the Canadian Section of the Society cannot be found in the 21 Sections of the S. A. E. The officers and members of that Section are promoting in a highly satisfactory manner the regular activities of any Section and in addition have inaugurated a research fellowship with the Ontario Research Foundation. At present this fellowship embraces a practical research project on automobile fabrics.

Headwork *versus* Footwork

Annual Dinner Address

By Knute K. Rockne[1]

I HAVE been waiting a long time for a chance to talk to engineers, because our engineering faculty has been talking to me for years, and the thing they generally say is, "He can't play; he is down in his classes." Though we had a very embarrassing experience about 2 weeks ago. One of my players whom I carried 20,000 miles last fall flunked in geography.

I was going to talk on a little thing that we found out in the climate of Los Angeles. One of our engineering faculty said, "Why did you use the huddle out there, the only game in which you used the huddle?" You know, we use octant numbers in our shift, all a question of rhythm and timing. I said, "I was afraid of the effect of the heat and humidity on the detonation."

Interference, of course, is the backbone of football, but sometimes it is misunderstood, as happened on one occasion when I was down in Atlanta to play the Georgia Institute of Technology. After we had worked out Friday afternoon, Coach Alexander, of the Tech team, came to me and asked if I wanted to see a real football game, and I said, "Why, certainly. I have plenty of time, it is only half-past two, and I just want to be back in time for dinner." He said, "Come on out."

As we were driving out he told me about this game between the colored schools for the championship of Georgia. I think he said Booker Washington College and I Will Arise Normal. I could not find those names in the Red Book and I think he was spoofing me. They had an amphitheater full of enthusiastic darky folk; cheering sections, cheer leaders dancing up and down, brass bands and all that sort of thing. After I had found my seat and begun watching this game, the chap who caught my eye was a little squat, heavy-set, coal-black quarterback on the college team. You could see that he was boss, and he was exuding personality from every pore. For instance, he would stand there behind his center and would look over this other team with a little contempt in his eye, and then when he got all ready he would turn around to his backfield and begin calling numbers. He would holler, "Eight billion," and his team mates would call back, "Boy, that's it, eight billion! You tell 'em, brother! Four hundred thousand! Glory be!" The ball was passed, and away they went. No number under 100,000. To make a long story short, the coach of the college team was not an engineer but a strategist, and he was saving his ace in the hole for the psychological moment.

In the middle of the second quarter the normal team fumbled in midfield and the college team recovered the ball. An instant later considerable commotion occurred on the college bench. Suddenly there came forth a great, big, handsome darky about 6 ft. 4 in.: he certainly could strut. When the crowd saw him, they went crazy. Pandemonium broke loose. The team was lined up, with the new man in the key position, the man who receives the ball from center. The referee blew his whistle, and the crowd all hushed with awed expectancy, as this new fullback stood there with his chest out about 12 in. The little quarterback turned around and began to call his numbers, "Nine billion!" Nine team mates all chorused it back in unison, all but this new fullback. He leaned over and said, "Never mind any of those fool numbers, boy. Just pass the ball, that's all." They passed the ball to him and he caught it and tucked it under his right arm. As he started for right end with great, long strides, and his knees around his chin, he hollered, "Interference, follow me!"

I was talking to Mr. Kettering and I told him that we had very few engineering students in our football squad on account of the heavy curriculum. I said most of our football players are liberal arts students, with accent on the liberal. Then we began talking about a couple of my sons. I told him how one of my boys was going to be a football player, and I did not think the other one was. I told him one of them was going to be an engineering student, I thought his bent of mind ran in that direction.

He said, "Are you going to allow him to play football?" I told him yes, I thought that football could add something to his education. I know as I look back over the teachers I had in my time, and you probably can do the same thing, the men who stand out, and one or two women, are the teachers who taught me more than the facts contained between the covers of a book. I remember very gratefully the ones who did more than give me the facts. They stirred my imagination. They stimulated me to continue study after I was through school. They gave me part of themselves. They gave me a zest for life itself, and I think that football would be an adjunct to this young man's engineering training because most of our teachers in engineering now are research men who look upon human beings, particularly boys, as mental automatons, and I believe that they can get experiences there that will enable them to get along just a little better in their human relations.

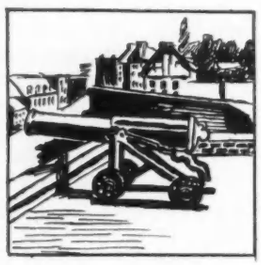
You say, how? We give them certain experiences that help them, because to belong to our organization we insist upon certain things. I do not know what the requirements are to belong to the S.A.E., but we re-

[1] Director of athletics, University of Notre Dame, Notre Dame, Ind.

quire certain things in the candidates for the football team and we insist upon them.

Eliminating the Unsuitable Candidates

In the first meeting in the fall we have about 350 boys sitting in the room, and I talk to them about the four kinds of boy I want to get rid of just as soon as I can. We do not drop anyone off, but they drop off by themselves generally, with a few exceptions. I say first of all is the fellow who had a good year last year and is suffering from swelled head and dry rot. He intends to rest on his oars or his last year's reputation. I tell them he is in for a shock, because somebody will be in his place. Second is the griper, the disorganizer; nobody is right but himself. Well, as soon as I find out who he is, when he comes out for practice some night, he does not find a suit in his locker. Third is the quitter, the fellow who wishes he could make the attempt, but who has not the character to pay the price. I tell the boys, if any boy of that type is present for him to quit that day. Then, the fourth class of boy I desire to leave immediately is the mucker, the fellow who has not enough character even under the stress and strain of a bodily-contact game to show those forms of generosity we know as sportsmanship.



A week later, after a few of the boys have dropped out, either voluntarily or otherwise, I talk to them about four other things. I tell them, first of all, that the kind of a man we want to drop out now is the chap who is alibi-ing. I say, "Many lads here who are wonderfully built physically and seem to have mentality above normal are failing, and they are failing because they are alibi-ing themselves, they are justifying defeat." And I tell them that nothing can justify defeat as regards themselves. The second class of boy is the one who is feeling sorry for himself, and he is out right away. I do not need to discuss any fellow who feels sorry for himself. The main trouble with him is that the fiber and osseous tissue in the backbone has changed to a collodial substance. A third class of lad is the critic. He looks in the mirror and admires, and looks at his team mates and criticizes. I tell that class of lad, "Change that over; look in the mirror and criticize, and look at your team mates and admire, and be inspired by the good points of these players around you. If they have any faults, I may mention them." A fourth class of lad suffers from an inferiority complex. Due to some faulty environment in his youth he does not think he is very good, he does not think he has much ability, and he says, "What chance have I to compete against 350 boys out there trying to make a team of 11 men?" I tell that kind of a boy, "Forget your inferiority complex and get a superiority complex. Go out there feeling you are just as good as any man there, and that you intend to show the coach you are good enough to make that first team."

I remember a little lad who played this fall. When he first came out I divided the team up: ends, guards, tackles, centers and so on. I walked over to the group of guards, a line position requiring big men, as a rule. There were a dozen great big huskies and this little chap named Metzger. I said, "Aren't you out of position?" He said, "I do not think so." I said, "Aren't you a little small to play guard?" He said, "Yes, but I am also a little rough."

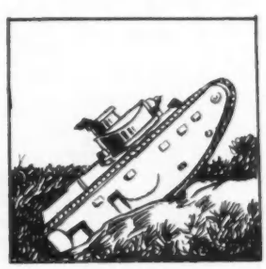
Team Play Very Essential

Just before the first game of the year I call them together again and I talk to them about team play, and that is not a very easy thing to put over with high-school boys, because many high-school boys have been spoiled by the press, and many of these boys are stars, wonderful players; if you do not believe them, they have clippings along with them to prove it! But you cannot succeed without team play.

I remember an incident about a young lad who came out and looked all right in every place, did everything exceptionally well, his execution was remarkable; and so, when we played our opening game of the year, a small practice game, we decided to use this young fellow, and lo and behold, they called his number, and three times this chap ran 60, 70 or 80 yd. down the field for touchdowns. The morning paper came out the next day and I was curious to see if our local sporting editor would give credit where credit was justly due; would he say that the team looked good because the blocking was superb? But no, this sporting editor knew what his public wanted, and he had a big streamer headline that read: New Horseman Looms on the Horizon of Fame; The Kokomo Flash! The next day six columns telling about him and three or four pictures were printed. The next thing I knew this young fellow became afflicted with a very common disease we have in athletics known as elephantiasis of the occipital lobe; not a very dangerous malady, but the young man so afflicted is worthless for the time being. We gave him the usual serum treatment, which was ridicule from his team mates and the student body. That always reduces the fever and the swelling.

When we went to West Point a couple of weeks later to play the Army, we decided to play the young fellow again, thinking he had entirely recovered. I remember that afternoon very well, because the boy's father and mother were there to see the lad perform. And after 10 min. during which this young man had posed around, evidently wondering how he looked from the grand stand, I took him out and put in his place a little third-string halfback who was anxious to come out and do his bit for the team, and we were lucky to nose out the Army that afternoon in a very hectic contest.

We left for home immediately, and Monday, after the day's classes were out, we assembled for our first practice, and the young Kokomo Flash was sulking in the corner and I did not pay any attention to him. Tuesday he came out and was still sulking, and I still ignored him. On Wednesday he came over to me and said: "Coach, I am handing in my suit." I said, "Well, I was just thinking of asking you for it." He said, "Well, you know the most disgraceful, most humiliating, most unfair treatment I ever got in my life was the way you disgraced me in front of my folks last Saturday."



I said, "Don't you know why?" He did not seem to, so I said, "I will refresh your

memory. We received a kick-off, reached the 3-yd. line and then stopped dead. George Gipp sent a long spiral punt soaring 50 yd. down the field. Your team mates ran down that field just as fast as they could, in order that the Army could not bring the ball back an inch; all but you. You were jogging down the field very slowly. A little bit later we got the ball. Again we could not gain. Again George Gipp sent one of those long spirals soaring away down the field. Again nine of your team mates gave all they had as they ran down that field, covering that kick; again, all but you, the fancy prima donna. You were still gamboling very leisurely, still saving yourself for later on when you would hear your number called, make some long runs and achieve the headlines in the New York City papers. But I thought we would overlook it.

"A little bit later, the Army, on their own 20-yd. line, fumbled and we got the ball, and as we lined up with the ball in our possession, 20 yd. from their goal line, Brandy (the quarterback) turned around, and said to you, 'Boys, let's put it over right now!' He turned around and barked those numbers out clear, crisp and staccato, calling for a play in which the ball would come to you, and you would run around right end. The ball came to you, and you started around right end, but running just in front of you was George Gipp, the other halfback, and his duty and responsibility to you was to take that Army left end out of the play and keep him out, and he did. As a result you wiggled and squirmed for 11 yd. until you were tackled.

"The stadium re-echoed to the cheers of the crowd, mentioning your name. We lined up, and Brandy again called the play numbers, calling for the same play, except this time around the other end. This time George Gipp carried the ball and your responsibility was to do for him what he did for you, namely, take the Army right end out of the play and keep him out. But what did you do? You did not even annoy that end, and as a result he came through and threw Gipp for a 4-yd. loss. As we lined up Brandy called the play over again, gave you a second chance to see if you could not fulfill your obligation. Now, what did you do? The second time you went out and leaned against this end, and the end tossed you to one side and threw Gipp for a second loss. So," I continued, "I took you out, not because we failed to score at that particular opportune moment, but because you had no sense of responsibility or obligation, not so much to me as to your own pals on the team; and so," I said, "now, I am going to save you." He asked, "What for?" "The Junior Prom," was my reply.

But the lad was made of pretty good stuff and he stayed out, and the next year made the team. Since that time I hang up a lot of signs in the locker room thinking they might have a considerable effect on impressionable youth, and the one I like the best of all is the one that reads:

> Success is based on what the team does,
> not on how you look.

And I have not had much trouble along that line since then, though now and then I have to hang up that sign in some individual locker. Whenever I do, the boy will take the sign and carry it back and say, "You have got me all wrong, coach!" I answer, "What? Was that hanging in your locker? I beg your pardon!"

Now, I don't know much about team play of engineers, but I wonder if all of you have the sympathetic knowledge of the other branches, including the salesmen, the service man, the advertising man, the credit man, the production man, the fellow who dresses the window, or the bookkeeping department, all going to make up the team without which no success could be achieved. You men are now complaining that salesmen are not doing their stuff. I wonder if you have a sympathy for the manifold problems with which they are confronted. Salesmen tell you, of course, the same kind of story I heard out in Utah one summer. I came out and remarked, "Gentlemen, it is awfully cold here.' They said, "Yes, it will not get warm until the snow melts in the mountains." I queried, "When does the snow melt in the mountains?" "Well, not until it gets warm," was the answer.

"But If Hope Eludes You, All Is Lost"

And then along about the middle of the year, when the tough games come along, I talk to them on another psychological phase. I was given a big thrill one summer, about 1926, when I was in New York City and visited The Players as the guest of Lawrence Perry, the author; and as he was taking me through the club he was explaining how it was founded by Edwin Booth, famous Shakespearian actor, and how Booth as its first president always maintained the high quality of membership and all that sort of thing. Finally, as we were walking along we came into a small room containing a table and a chair, and he said that in his old age, after Booth and Barrett had both retired, Edwin Booth was wont to sit there and read in the afternoon. One afternoon, as he sat there, he passed away. And my friend said, "In his memory, ever since then we leave that table and chair just as you see them there, and that book he was reading is open at the exact page he was reading at that particular moment." I was very much impressed and somewhat intrigued. I leaned over to see what Edwin Booth had been reading and found that it was extracts from some old poems; you may remember them from McGuffey's Fourth Reader. The first line reads, "Hope springs eternal in the human breast," but, going down on the page, the last line reads, "But if hope eludes you, all is lost."

I brought this message home to our lads, and we went on through the season until the last game at Los Angeles, against the University of Southern California. The score was 7 to 6, with 8 min. to play, when suddenly these California lads rose up in their wrath and began going through our guards and tackles for 3 and 4 yd. at a clip. Down the field they went, and finally, after they had gone about far enough, I changed the guards and tackles, and they went through even faster, right over our goal line for a touchdown, making it 12 to 7 in favor of our opponents, and my watch showed 3 min. to play. Apparently the game was all over but the shouting. Our boys elected to receive. The ball went over the goal line and was brought back to the 20-yd. line, where we put it into play. We tried three plays and did not gain an inch and, on the fourth down,

we punted to Southern California, who to my delighted surprise punted right back to us. As I saw our team on that 20-yd. line trying three plays, I saw 10 men who were still doggedly giving the best that was in them, still trying just as hard as they could, but the eleventh lad, a little substitute quarterback about 19 years of age—who can blame him?—as far as he was concerned, the game was over. Hope had eluded him.

I turned around to a little chap sitting alongside of me, a chap named Art Perisine, a quarterback who had been hurt somewhat about six weeks previously. I said, "Art, how do you feel?" He said, "Great!" I said, "Do you think you could go in there and pull old 83 or 84 out of the bag, those left-hand flips of yours, and possibly pull this game out of the fire?" Before I was through talking he had his headgear on and was leaving for the field. As he did so, he turned to me and said, "Coach, it's a cinch!" Now that may have sounded like egotism but it was not. Once I heard a chap define egotism as the anesthetic that deadens the pain of one's stupidity, and I can assure you it was not that. It was confidence. He had done it before and he felt he could do it again.

So out he went, and in the first play he pulled a spinner through the line with himself carrying the ball for about 9 yd., after which he took time out. You could see him call those 10 team mates around him and you could see him buck them up with his own optimism, and you could see them rise up out there. I said, "Maybe we still have a chance," though I was not hoping for very much. They lined up. About 1½ min. was left to play and the first thing I knew Perisine did pull old 83, and he flipped a 30-yd. pass to a chap named Ecknor, then a wide end-run for position, and with less than a minute to play, out came old 83, and he threw a similar pass for a touchdown which was the winning touchdown. The touchdown was interesting but not important. The important thing was that he had learned the psychology of perseverance, of sticking in there regardless of how hopeless the outlook, regardless of how impossible the situation appeared.

Must Depend on Engineer's Creative Ability

I have always had the highest respect for the engineering profession, mainly, I presume, because I could never do anything but mathematics, and I have always, seriously, had a high regard for the men who do things, for the men who build things. I do not see but what in the future the average layman in America will depend to a very great extent on the leadership, on the vision, on the creative ability of the engineering profession. I do believe that engineers, with their emotional control—and that is all I have been discussing here—with ability to handle their emotions, the men who know how to play the game, the men who play "cricket" as they say over in England, are the ones who will lead us in the future.

Now, I have talked to engineers who were devoid of emotion, calculating men, and they are fine. I have no quarrel with them at all. They are generally the research men, who solve problems. Many engineers, however, must work with human beings. They overlap, they dovetail, they coordinate with the salesmen and with all the other departments I have just mentioned, and to do that you must be able to handle your emotions.

A professor of engineering came into our dressing room one time before a game. He said, "I do not believe in any such thing as emotion, nothing counts but cold intelligence." I disagreed with him. He said, "Let me hear what you have to say to this team."

What I say to a team before a game is no mystery. Take, for instance, that Carnegie Institute of Technology game, where we expected to be beaten three touchdowns, and I said so. I was called a psychologist. Here they were going out on the firing line, ready for the game, the bands all through playing, officials out there ready to blow their whistles. I told our boys, "You are playing against the boys from Carnegie Tech, a fine team, a great team. But," I added, "I think you are just as good. Now," I said to these lads, "I think I know just about what kind of shape you are in physically, and I think I know just about how much football you know mentally, but I do not know one thing; I do not know what is in your hearts." And I added, "The game will be won or lost today on what is in your hearts, and I want you to go out there and show 50,000 people just what is in your hearts!

"We will probably win the toss and kick-off," I continued. "I want you to run down the field and tackle them and go on the defensive. Stop them dead and take the heart out of them! You men in the backfield, be alert, heads up, smart; look for that ball when they throw a forward pass, and when they do, go in and get that ball. I want you to block as you never blocked before in your lives. I want you to do as well, as hard, as mechanically perfect as you can think of. And the quarterback, think clearly and call the right play; and you men, all 11 of you, dig those cleats in deep, get your jaws set, and when you start off for that goal line—drive, drive, drive!"

That is the reason why I like that sign, "Let's go!" Because if you go, you go.

A Survey of Mobile-Type Diesel Engines

Annual Meeting Paper

By C. G. A. Rosen[1]

MAJOR problems involved in the designing of high-speed Diesel engines that are to be commercially successful are discussed. The object of the author is to present in the paper those factors of design which assure good operating quality. Preconceptions of operating conditions have been the greatest handicap encountered by the oil engine. The designer must turn to pure science for the fundamentals and investigate qualitatively the great accumulation of research data on the internal-combustion engine to determine the bearing of combustion theory on operating results.

Combustion-chamber design; fuel-injection methods and devices; flexibility in the utilization of a variety of cheap, low-grade fuels; completeness and smoothness of combustion; reduction of vibration; and low first cost and maintenance are principal points discussed.

Unification of the best features and types and happy compromises of the desirable characteristics are needed to increase the manufacturing and sales possibilities.

COMPARISONS are said to be odious but, to the engineering analyst, they are tools of potency; they are a means of discrimination. In making a survey of existing types of mobile Diesel engines, the comparative method will be employed in an endeavor to reveal points of superiority. The object of this paper is to cull those factors of design which assure good operating quality. For the sake of clarity, good operating quality is here defined as reliable operation at economical maintenance.

To build the skeleton of an ideal oil engine, one must become thoroughly imbued with conditions prevailing in service. Too often a Diesel engine succumbs on the field due to disabilities inherited from drawing-board prejudices. The greatest handicap which the oil engine has encountered throughout its entire history has been preconceptions of operating conditions induced by biased opinions.

The finished Diesel engine is a properly proportioned accumulation of many details gathered from the test field of experience. Operating economies generate the seed for repeat orders. Therefore, why not place the highest emphasis on design factors which yield the best harvest? C. F. Kettering has been credited with saying:

> The red bank-balance is nothing but the hisses of the community, and the black bank-balance is the applause of the community. If they like the product, they are willing to pay more than it costs to make it.

Must Tie Pure Science and Practical Design

The field of operation having been determined for the oil engine, the designer must invade the realm of pure science for a thorough grasp of the underlying fundamentals which will create the mechanism ultimately destined to produce the desired operating quality. The vast store of internal-combustion-engine research must be investigated qualitatively to determine the bearing of combustion theory on operating results. To quote Prof. H. C. Lea:

> In the solution of many problems in design, in processes, in materials, as well as in the discovery of new methods, it is necessary, as Francis Bacon would today remind us, "To apply natural philosophy to particular problems, and particular problems must be carried back to natural philosophy."

Much remains to be done in the research on the combustion process. Extended effort is required to organize accumulated information into a related structure of usable form. The present status of high-speed Diesel-engine development indicates that ties are not yet directly drawn from operating quality to pure science. The limits, however, are narrowing between these two extremes. Practice reveals the variety of compromises which have been made, as demonstrated in the constructions offered.

In gasoline-engine development, Alex Taub's correlation of combustion-chamber design,[2] shows a unidirectional tendency toward a common goal in achieving good operating quality. The high-speed Diesel, however, is in virtual opposition and spreads out to a diversity of designs for obtaining compromised results. The former development is converging; the latter, diverging. Surely there must be some simple method of burning heavy fuels quickly and completely in a correctly modulated and flexibly controlled manner. The universal gasoline engine burns volatile fuels satisfactorily; the established large Diesel engine consumes heavy oils with proved advantages. Certainly, therefore, the high-speed oil engine, as an economic need, should have a definite character in practical applications. The three are undoubtedly interrelated but lack of assimilated knowledge prevents tracing the lineage.

The development of fundamentals associated with high-speed Diesel engines has been responsible, to a great extent, for the recent substantial progress in large solid-injection Diesel engines. For instance, spray re-

[1] Diesel engineer, Caterpillar Tractor Co., San Leandro, Calif.
[2] See S.A.E. JOURNAL, October, 1930, p. 437.

searchers have advocated forms of combustion-chamber design to accommodate fuel sprays of calibrated speed and penetration. The delving into difficulties in burning liquid fuels in small cylinder-bores has led to the rather recent explanation of ignition and its delay-period characteristics. Although Diesel engines have been built for more than 30 years, the designer has been influenced by speculation in laying down designs and has resorted to cut-and-try methods for confirming experience. This state of affairs narrowed the limits of application of the Diesel and led to rather rigid empirical formulas. The manufacturer, therefore, clothed the oil-engine design in a veil of mysticism. The high-speed Diesel, however, was devoid of precedent and the designer was consequently forced to search for larger horizons in order to overcome the problems impeding its progress.

Combustion-Control Systems Need Unification

The great variety of existing fuel systems, all of which endeavor to accomplish the same ultimate result, calls for the unraveling of that elemental thread of combustion phenomena which is woven into the fabric of every fuel-burning system. Until such time as combustion control can be definitely predetermined in a given practical design, the Diesel combustion method cannot be unified and reduced to its simplest form.

Ricardo has aptly divided Diesel combustion systems into four distinct classifications,[1] in substance as follows:

(1) Open chamber provided with multiple sprays of very high injection pressures

(2) Precombustion-chamber systems of moderate injection pressures

(3) Open chamber provided with organized unidirectional air-flow across the fuel spray injected at moderate pressures

(4) The Acro system employing moderate injection pressures

To the above should be added a fifth classification, namely, the low-compression spark-ignited oil engine.

These basic fuel systems predetermine variations in engine construction which are further greatly multiplied by differences of opinion regarding valve disposition, combustion-chamber allotment, injection-valve design, fuel metering, injection pressures, and so on. The great multiplicity of possible designs is emphasized by comparing the magnitude of experimentation now being conducted throughout the world with the minitude of types at present available. Probably a period of years will be required to concentrate types, but ultimately combustion research will point to a select system, industrial experimentation meantime eliminating the unfit. Today, a measure of hesitancy exists but the high-speed oil-engine's tomorrow undoubtedly is assured. Its possibilities have been too well demonstrated. Only the lack of cataloged combustion knowledge prevents the wider application of the high-speed oil engine.

Should Utilize Cheap Residual Fuels

From an economic standpoint, what does present experience dictate as desirable characteristics for the high-speed Diesel engine?

As an economic entity, the mobile type of Diesel engine should burn available fuels with a fairly wide range of characteristics. The two most attractive features of the compression-ignition engine, when compared with gasoline engines, are its lower consumption of fuels and the present lower price of the fuels used. Opportunities will develop for further reduction in Diesel fuel consumption but there is every reason to believe that the price of Diesel-engine fuels will rise. The distillate fuels at present advocated for high-speed Diesel engines are virtually a waste product. They are obtained by distillation and form a very narrow band of distillate between gasoline and residual fuel. The yield of straight-run gasoline has been constantly increasing and at present has reached a practical limit. The ever-growing demand for gasoline has fostered the cracking process, which in time will make available for gasoline the stocks now used for Diesel fuels. On the other hand, oil-engine manufacturers may induce the oil industries to force the distillation process to yield higher percentages of distillate fuels. By developing the maximum yield of distillate fuels by increasing distillation as far as practical and using none in the cracking process, it may be possible to obtain 65 per cent of the crude for Diesel fuels.

Other pertinent requests are being made for Diesel fuels for domestic heating plants, by-product production, certain Diesel powerplants, motorboats, motorships provided with limited fuel systems, and so on. When the high-speed Diesel becomes popularized, the demand for Diesel-engine fuels should increase rapidly. The apparent possible dwindling of the supply of this fuel, together with its increase in demand, would naturally cause the price to rise as compared with that of gasoline. The price differential would, therefore, be less favorable to the Diesel. The entrenched economic position of the high-speed Diesel would then be threatened unless it were capable of consuming cheaper fuels.

Furthermore, the distribution of motorship fuels of heavier grades throughout world ports makes this commodity available for mobile Diesel equipment. The characteristics of this fuel, however, are quite variable and often are beyond the limits of specification fuels for high-speed work. Here again the mobile Diesel is assailed unless its fuel system accommodates itself to locally available fuels.

The future high-speed Diesel will be limited in distribution and retarded in development unless the combustion process be sufficiently flexible for the engine to consume those fuels which economic conditions present for its use. At the present outlook a relative abundance of residual fuel exists. There seems to be no present fear that petroleum processes will remove this product or that competition for its use will become sufficiently great to cause its price to rise exorbitantly. Fuel authorities are agreed that, for many years to come, residual petroleum fuels will be the cheapest petroleum product. Why not entertain the use of these fuels for mobile equipment? Surely the primary assurance of the future security of the high-speed Diesel engine lies in its ability to maintain its economic status.

That the successful consumption of residual fuels is possible in high-speed Diesels has been positively demonstrated. For practical operating purposes, however, certain restrictions should be made. Portable equipment of small bores requires free-flowing fuels of a possible maximum viscosity of 100 sec. Saybolt Universal at 100 deg. fahr. The pour-point can vary somewhat with climatic conditions. The use of heat for reducing viscosity is possible but is annoying because of the nuisance of clearing the fuel lines on stopping and starting. In a well-designed combustion system,

[1] See *The Automobile Engineer*, April, 1930, p. 153.

viscosity and impurity seem to be the only properties requiring limitation. Centrifuging successfully removes the undesirable impurities; the opportunity of blending residual oils with lighter fuels for the purpose of reducing viscosity therefore presents avenues of usefulness for this cheap petroleum product in high-speed Diesels.

Economic maintenance presupposes completeness of combustion. The ideal fuel system should consume the cheaper fuels with the minimum of wear on surfaces in contact with burning gases. As a rule, high maintenance is directly proportional to the degree of imperfection of combustion or the lack of control of combustion. Low maintenance is to be more highly stressed than low fuel-consumption.

Desirable Factors for Economical Operation

Having agreed, then, that the economic advantages of the Diesel engine should be maintained, what practical considerations are involved for good operating quality? A correlated analysis seems to point to the following desirable factors:

(1) Minimum fuel-system maintenance, with maximum operating reliability obtainable by the use of a single-hole orifice channeled to a single-plunger fuel-pump for each cylinder

(2) Colorless exhaust at all operating loads and speeds, effected by sustained pressure fuel atomization with positively controlled beginning of the injection period and sharp cut-off

(3) Individual measuring type of fuel-pumps for close regulation of minute fuel quantities, to assure accurate distribution to the cylinders for satisfactory idling and slow-speed operation

(4) Rapid heat transformation of the injected fuel by good distribution, obtainable by means of high temperature and correctly proportioned turbulence

(5) Reasonably low maximum pressures reached at limited acceleration rates of pressure rise

Single-Hole Injector Nozzle Preferable

In building the design of the fuel system and giving due consideration to the fuels to be burned, the engineer perhaps places first emphasis on the injector. This mechanism serves his final desire for control of the liquid combustible. Beyond this point, combustion reactions completely alter the scheme of events. The designer's ideas for the injector may be governed by a variety of influences. Ease of manufacture may have first appeal; the use of a purchasable valve may have precedence; but, after all, the Diesel engine is an oil-burning power unit and should perform this function to the best ability of the injector.

The nozzle provided with a single-hole orifice has primary practical advantages. It is simple to construct and easy to maintain. It provides only one channel of flow for the fuel and, therefore, does not destroy distribution characteristics as does a multiple-hole orifice when one or more holes become choked. Whatever fuel leaves the fuel-pump discharge valve will always enter the cylinder in the same directed course. The single-hole nozzle permits of heavy smoky overloads, as correct spraying characteristics can again be attained when returning to normal loads. A smoky overload often destroys combustion equilibrium for subsequent normal load operation in multiple-hole nozzles. The single orifice fosters the use of automatic turbulence means for fuel distribution and therefore is quite insensitive to normal orifice erosion, as considerable spray-cone variation is permissible in this type. Single-hole orifices are relatively large in diameter and consequently minimize straining difficulties. The use of the heavier grades of fuels is practically limited to single-jet sprays.

For simple construction, the open-nozzle injector holds first place. Its size and shape can usually be molded to fit into any desirable locality of the combustion-chamber border. This has advantages in the disposition of exhaust and intake valves and permits the distribution of metal for effective cooling. The simplicity of the open nozzle, however, throws added burdens of responsibility on the fuel-pump. A high rate of pressure rise is required at the discharge orifice. This condition is rather easily obtained for a relatively narrow operating range, but combustion difficulties are often encountered under variable load and idling operation. The fuel channel is proportioned to give correct spray velocity at full load but is not easily synchronized to qualify for slow-speed or no-load running. The fuel-pump mechanism can be called upon to remedy this condition somewhat, but the functions of the fuel-pump are manifold at best and should be reduced to the minimum for practical purposes.

Combined Fuel-Valve and Pump Injection

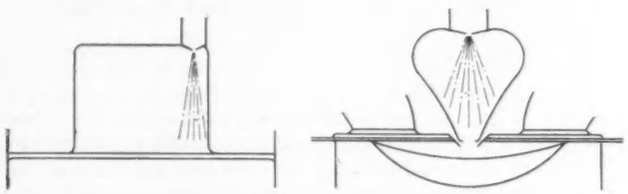
The mechanically controlled fuel valve has operating advantages in that means are available to the operator for the control of fuel-flow at the last point in the fuel system. Cam actuation of the fuel needle, together with channel control behind the valve seat, presents opportunities for predetermining the combustion line for all loads and speeds. Combustion efficiency can be maintained throughout the whole operating range. This arrangement reduces the functions of the fuel-pump to supplying fuel and maintaining the hydraulic head. Mechanical complications, however, seem to be its weakness, as expansions and distortions affect the requisite accurate timing. Inertia influences are also troublesome at high speeds and light loads. In the common-rail system equi-calibration of fuel metering among the cylinders is often difficult to attain, especially at governed idling. The position of the fuel valve, and consequently the layout of the combustion-chamber, is dependent upon valve-gear design. The disposition and design of exhaust and intake valves is therefore relegated to expediency rather than to preferential cooling, desired gas velocities, and the like. The need of accurate adjustment and careful settings may offset its combustion advantages in the field when used on mobile equipment.

The automatic type of closed fuel valve probably is an acceptable compromise, provided its associated fuel-pump is in tune with its functioning at all loads and speeds. It certainly is a simple valve and is readily serviced and replaced without field difficulties when manufactured with the uniformity characteristic of trained experts. This valve serves to satisfaction at slow speeds and idling when the fuel channel maintains the proper atomizing quality and the fuel-pump assures sharp cut-off. Variable-load operation must request the combustion-chamber to be an obedient servant by providing the necessary reception of oxygen for regulated combustion.

Perhaps a compromise between pump injection and mechanically actuated fuel valves will ultimately win a place by employing the fuel-pump solely as a measuring

instrument to deposit fuel in the valve body prior to the injection period. Thereby much relief is given the pump mechanism, and high accuracy of metering can be attained. The storage of fuel at correct spraying pressures would then await the moment of valve-needle lifting which would signify the injection start. A cam-controlled tripping or unbalanced means could initiate this event. The rate of fuel-flow would automatically follow by channel control directly behind the fuel-valve seat. Cessations of injection and seating of the fuel needle would immediately follow after the storage means had yielded its measured fuel.

The fuel-pump design goes hand in hand with that of the injector. The minimum of functioning is desired above all things for the fuel-pump. Its ability as a metering device is well established and, with the growing tendency toward moderate injection pressures, its metering accuracy is increased. Successful elimination of inlet-valve leakage is much desired. The most vulnerable point in the Diesel engine has always been the fuel-pump suction valve. The production of power is decidedly dependent upon the correct seating of this valve. Consistent performance and reliability impose ruggedness of construction on the fuel-pump, coupled with simplicity of design. In its most practical present



TYPES OF DIESEL-ENGINE COMBUSTION-CHAMBER DESIGN FOR CONTROL OF COMBUSTION

Case *A* (Left) Regulates the Rate of Fuel Feed, Whereas Case *B* (Right) Has a Precombustion Chamber of Limited Oxygen-Content. Combustion Quality Can Be Made All That Is Desirable in Both Cases, but *A* Gives Lower Fuel Consumption and Higher Brake Mean Effective Pressure, Whereas *B* Gives Greater Combustion Smoothness and Permits High Sustained Brake Mean Effective Pressures

form, we find the cam-actuated pump, provided with suction ports and sleeve-bypass governing on the discharge side, to be quite acceptable and applicable to a wide range of injector types.

Combustion-Chamber Design of First Importance

The combustion-chamber is here indicated as third in sequence, when, as a matter of fact, it is first in importance as far as the successful consummation of the combustion process is concerned. The injector, fuel-pump and combustion-chamber are intimately related and form a composite unit in the combustion system. The status of oxygen content in the compression space during the injection period has a direct bearing on the ultimate results of combustion obtained.

Complete combustion requires a thorough intermixing of air and fuel, both of which are properly prepared to enter chemical reaction. The fuel particles which first enter the arena designated for their consumption should be met by highly heated air currents endowed with an affinity for their equivalent and inherently qualified to immediately form supersaturated oxygen compounds which decompose with extreme rapidity and thereby create ignition. The flame having been started, the unburned fuel particles which have thus far entered during the delay of injection quickly find their equivalent for combustion. As a matter of fact, this second stage in the combustion cycle is usually far too rapid, and the rapid rate of change in pressure is responsible for combustion roughness. Two avenues have been sought for its control; one is purely mechanical and involves regulation of the rate of fuel feed, and the second is automatic by allotting this preliminary combustion to a special chamber of limited oxygen content slightly removed from the main combustion-chamber.

Up to this stage, approximately 20 per cent of the full-load fuel charge is consumed. This part of the process can be easily accomplished by the use of a single-jet fuel spray. The combustion of a further quantity of fuel requires means for making intimate contact of the remaining air in the combustion space with the continuously entering fuel-flow. To apply the single-hole orifice at moderate injection pressures to the third phase of the combustion cycle, two solutions are offered, both of which are automatic in operation. In one case, the air of combustion is in a moving stream so directed that fresh-air currents cut across the flowing fuel-spray at the desired rate of commingling and carry the burning fuel-molecules away from the vicinity of injection until their energy is dissipated in regions sufficiently remote to prevent the final products of combustion from influencing the burning of the last portion of fuel injected. In this instance the air-flow is set up prior to combustion, as is practiced in the Ricardo engine.

In the second case, the continued injection of fuel into the burning gases, temporarily stalled in the auxiliary chamber, transforms the unburned fuel to a state of avidness for oxygen. The burning fuel-molecules serve as energized vehicles to carry the yet unburned fuel at extremely high velocity into the vicinities of fresh oxygen.

In the former case, the air of combustion is caused to flow and enter relationship in correct proportions with the entering fuel. In the latter case, high-velocity fuel-laden gases permeate the air content and in transit acquire the chemical status necessary for combustion.

Control of the rate of burning during the third phase of combustion is, in the former case, largely mechanical in that it is effected by the cam profile of the fuel-pump; whereas, in the latter case, this function is best accomplished by automatic volume-control of the burning gases. The former combustion-chamber assumes a concentrated shape; whereas, in the latter case, the non-compact form lends itself to advantage.

For the sake of clarity in continuing the comparison of the two types of combustion-chamber that have been chosen for discussion, the first will be termed combustion-chamber *A*, while the second will be designated as *B*. It is not the purpose in this paper to reduce these two types to definite constructed designs, but to assume a theoretical case in which each combustion-chamber exemplifies a practical trend. Each example, however, can find partial application in a number of constructions.

Qualities That Must Be Compromised

Fuel consumption is ever an item of comparison in Diesel engines. Its quantitative value, however, is often more emphasized than its qualitative value. The shape of the fuel-consumption curve has a greater index of valuation than the actual minimum figure obtained. Approach to a flat parabolic curve is the uppermost desire.

Too often we find the hyperbolic form the more prominent in practice. The high-speed Diesel engine should be unshackled from the stigma of excessive fuel consumption at light loads and idling speeds. Combustion quality can be made all that is desirable in cases *A* and *B*. However, case *A* will be lower in fuel consumption and higher in maximum brake mean effective pressure than will *B*, because of the lower heat losses prevailing in compact combustion-chambers.

Combustion-chamber *B* exhibits greater combustion smoothness than combustion-chamber *A*, and therefore permits high sustained brake mean effective pressures, so that in practice the two cases just about balance in output. This question of combustion smoothness should not be ignored and the attainment of smooth combustion by simple automatic means is to be extolled. Volume control of the burning gases has more field-operating appeal than has fuel-volume control. In all designs, however, a practical compromise must be struck between low fuel consumption and smoothness of operation, between high brake mean effective pressure and low maintenance, between ideal full-load operation and wide speed-flexibility.

Good idling is always necessary in mobile equipment. All cylinders should bear equal responsibility in providing their quota for uniform idling, even under extended periods. Case *B* can be idled to lower speeds with positive ignition than is possible in case *A*. The ignition of the preliminary fuel charge is always the same regardless of load or speed in case *B*, and the attending thermal conditions remain nearly constant.

Ease of starting is directly proportional to compactness of combustion space. The more concentrated and the less divided the combustion-chamber is, the lower will be the required compression pressure. Case *A*, therefore, has superior starting characteristics over case *B*. In some instances, case *B* may even require the use of localized heat influences to assist starting.

First Cost Secondary to Operating Quality

The cost of manufacture of mobile Diesel engines has possibilities of considerable reduction. The immediately confronting problems are the unification of types and the establishment of confidence for the wider acceptance of a quantity-manufactured product designed to have good operating quality in field operation. The first-cost item would then reduce itself to secondary consequence.

The appearance of the low-compression high-speed oil engine as a contender for recognition cannot be denied interest. In many circles it is felt that 1000 to 1100 r.p.m. represents the upper speed limit of the commercial mobile-type high-compression oil engine. This restriction is not established by the combustion process, as extensive evidence proves. Combustion-chambers *A* and *B* each permit of speeds as high as 2000 r.p.m.

The real problems are initiated with the installation of heavier pistons and connecting-rods, such as are required for high-compression duty. Lower manufacturing costs draw limiting conditions around the construction of these parts, and field maintenance by unskilled hands is of economic consequence. The absorption of inertia forces, the prevention of vibration resonance, the reduction in influence of reciprocating inertia masses on clutches and gearsets, all militate to the advantage of lower compression-pressures. Not only is the engine itself affected by heavy reciprocating parts, but the moment of inertia of this mechanism is not constant and, in some cases, the variations are sufficient to substantially change the acceleration of the flywheel. This roughness in turning effort is an offspring of heavy masses involved in the reciprocating string of high-compression Diesels.

If combustion efficiency is sufficient to guarantee low maintenance with reliability on average fuels, the growth of the low-compression oil engine will be assured in types above 1000 r.p.m., as this field lacks serious Diesel competition. It appears that economic scrutiny and service demands favor the high-compression Diesel below 1100 r.p.m.; lower operating costs, superior lugging characteristics, and simpler and more positive fuel systems argue in favor of its future security.

The immediate aim of Diesel-engine development should be set toward the choice of fuel systems that are capable of accomplishing such operating quality as field service demands. The unification of types will quickly follow and manufacturing possibilities will enormously increase. In the words of Locke: "Where any particular matter of fact is vouched for by the concurrent testimony of unsuspected witnesses their assent is unavoidable."

THE DISCUSSION

E. T. VINCENT[2]:—Mr. Rosen is to be congratulated upon have given a very able summary of the Diesel engine covering a very wide field and obviously resulting from tests of a whole host of oil engines of different types.

One thing, however, I should like to see more light upon is the statement that recent progress due to fundamental research has resulted in the present activities; I rather object to the term "recent" in that connection. The association of spray forms with combustion-chamber shapes has been more or less common knowledge for a matter of 12 to 14 years. Engineer Commander Hawkes, R. N., published a paper in Great Britain in 1920 in which the elements of the phases of combustion, as recently elaborated by H. R. Ricardo, were propounded; also, in 1921, I read a paper before the graduate section of the Institution of Mechanical Engineers of Great Britain, in which the elements of designing the combustion-chamber shape to suit the fuel spray was propounded. So such developments cannot be called "recent." What has happened is that they have been given greater publicity because of the new interest in Diesel engines.

Again, has the designer of the high-speed oil engine been forced to something new? If one looks at the successful oil engines on the market today, he will find nothing new in them. You can trace the basic ideas in some cases back to the Ackroyd Stewart engine of about 1890, only we now have different materials and better detailed design, better fuel-pumps and machining of details and so on; but, if you get down to absolute rock-bottom, the fundamental principle of the engine, such as the method by which fuel is sprayed and whether it is sprayed directly into the cylinder or

[2] Diesel research engineer, Continental Motors Corp., Detroit.

into a separate chamber, and so on, is very little different. The old Lincolnshire oil engine, with its throat and separate combustion-chamber, is identical with some of the N.A.C.A. engines of today. Again, the RAE 20-T engine, a high-speed engine, is absolutely a copy, as regards the principles of the injection apparatus, of the Vickers submarine engine of about 1911. So not so much is new as one might imagine.

I thoroughly agree with Mr. Rosen that combustion control is where we have to look to for further improvements. I rather anticipate that the future will bring forth some form of mechanical operation of the fuel valve and possibly a combined valve and pump whereby the rate of spray will be exactly controlled, so that a smooth combustion-curve will be obtained and a high output secured from the engine without the use of excessive maximum pressures. I think that eventually the oil engine will equal or exceed in power output the existing gasoline engine. It should do so. I have already carried mean effective pressures of 125 lb. per sq. in. in two or three engines. In one particular engine it was possible to carry that pressure at a piston speed of 1250 r.p.m., with 650 lb. per sq. in. maximum pressure, for 10 hr. per day for 600 hr. No supercharger was used, so it is not just a snap record; it can be done continuously. We now have to find ways and means of doing this at high speed.

Mr. Rosen's fifth classification of Diesel engines, that is, spark ignition, should not be included. What does anyone understand by the term "Diesel" but a compression-ignition engine? Even though the spark-ignition type of oil engine may prove to be something worth while and have a large field of application, it should not be classed as a Diesel or compression-ignition engine. It may be that it is only a passing phase. Mr. Rosen himself expresses the opinion that the prices of Diesel-engine fuels are going to increase to probably about that of gasoline. If they do, the spark-ignition engine will become rather a doubtful commercial possibility, because its compression ratio is low and, even if its power output approaches that of the gasoline engine, there are all the difficulties of this latter type of engine such as the hot exhaust-valves and other troubles due to the type of fuel used, which is not the case with the Diesel engine. The thermodynamic efficiency of the spark-ignition engine probably will be slightly less than that of the gasoline engine because of the problems of detonation. If the fuel is refined so that it will not detonate, you no longer have the advantage of the non-inflammable nature of the fuel and an approach to the existing gasoline engine is made. So, eventually, when the price of fuel goes up, the spark-ignition engine may take on a totally different aspect to that which it has at present.

Production of Gasoline and Lubricants by Hydrogenation

Annual Meeting Paper

By R. T. Haslam[1] and W. C. Bauer[2]

AFTER briefly describing the hydrogenation process and its three characteristic reactions, purification, stabilization and homogenizing, that remain unaltered in direction although they all change in extent, the authors discuss the possibilities of applying the process to the production of motor-fuel and lubricating oil. The possibilities offered by the process of reforming the molecular structure of petroleum hydrocarbons along directed lines to obtain products of the so-called paraffinic or naphthenic type are stressed.

This presentation is supplemented by data on the actual properties and performance characteristics of hydrogenated gasolines and lubricating oils as tested by the fuel and lubrication laboratories of the Standard Oil Development Co. Two series of tests were run, one on a White motor-truck engine and the other on a Mack motor-truck engine, the latter being under abnormally severe conditions. Results of the tests are presented graphically and are also given in tabular form.

From these tests the authors conclude that hydrogenated lubricating-oils made from common crudes are superior to the best natural lubricants now available, high-grade naphthenic gasoline and blending stocks can be produced from relatively low-grade gas-oils and the hydrogenation process, when widely adopted by the petroleum industry, will apparently enable the automotive engineer to design engines that are capable of operation at greater compressions, higher speeds and higher temperatures with a resultant marked gain in efficiency.

Facts brought out in the discussion are that hydrogenated lubricants do not differ from current paraffin-base lubricants as regards oiliness and most of the bearing failures noticed by the author resulted from a breakdown of the oils, not a lack of oiliness. One of the discussers pointed out the desirability of having everybody become familiar with the octane-number method of rating the antiknock properties of fuels, since it represents a decided forward step and also provides a means for talking about the antiknock qualities of fuels in the same language.

BOTH from an engineering and from an economic standpoint the automotive industry rests upon liquid hydrocarbons of two types, the fuel and the lubricant. Possible substitutes for both are recognized, notably the alcohols as fuel and the fatty glycerids as lubricants. Technically these and other substitutes are of interest but commercially they are of no primary significance since hydrocarbons alone appear to be presently and potentially available in the required volume. Acceptance of this hypothesis led to the pioneer efforts to synthesize hydrocarbons from coal and water. The principles and the practical application of this synthesis have been the subject of a great program of industrial research and development initiated in Germany by the Interessen Gemeinschaft Farbenindustrie Actiengesellschaft and later carried forward cooperatively by the initiators and the Standard Oil Co. (New Jersey). That the field of the program covered not only the direct production of these hydrocarbons but also the whole subject of the constitution of the petroleum-hydrocarbon molecules was soon recognized, and from this point on it might properly be called the study of formation and reformation of the liquid hydrocarbons.

In this broader light the research became of importance to automotive engineers since it opened the possibility of not only the production of hydrocarbons generically to increase the available supply but also controlling or altering the constitution and properties of the synthetic products as well as hydrocarbons of natural origin to obtain that type of molecular structure which best lends itself to the requirements of the automotive industry. This paper deals with the latter aspect of the development.

Utilization and Object of Process

The result of this program has been the perfection to the point of initial commercial operation of a process known generically as the Hydrogenation Process. Although the process has many variants and other uses, those to be considered here are the production of gasoline and lubricants with particular reference to the properties of the products. The process, as at present applied to these uses, consists briefly in pumping the charging stock, together with hydrogen compressed to between 3000 and 4000 lb. per sq. in., through heat exchangers and a heating coil into reaction vessels containing a highly active sulphur-resistant catalyst. The oil and hydrogen flow through these reaction chambers where hydrogenation occurs, then back through the heat exchangers and coolers and into vessels that separate the gas from the liquid product. The hydrogenated oil is now ready for final distillation or finishing by regular refinery procedure.

According to the conditions of this hydrogenation treatment and the nature of the catalysts employed, the chemical reactions that occur alter their direction and extent. Three characteristic reactions remain unaltered in direction, however, changing only in extent in all cases. The first of these reactions is a species of purification, which has been called by Ellis[3] hydrocarboniza-

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[3] See Hydrogenation of Organic Substances, by Carleton Ellis, p. 513.

TABLE 1.—PROPERTIES OF OILS USED IN WHITE MOTOR-TRUCK ENGINE-TESTS

Oil	Hydrolube 75	*M*	*N*	*O*	*P*	*Q*
Gravity, American Petroleum Institute deg.	26.3	24.8	25.2	27.8	21.3	19.0
Flash Point, deg. fahr.	500	440	445	425	445	440
Fire Test, deg. fahr.	585	500	520	480	520	...
Viscosity at 100 Deg. Fahr., Saybolt sec.	810	747	741	651	1,400	1,356
Viscosity at 210 Deg. Fahr., Saybolt sec.	75.5	74	74	75	80	75
Pour Test, deg. fahr.	10	25	40	30	0	10
Color (Robinson)	9¼	¾	1	2	1½	5
Conradson Carbon-Residue, per cent	0.161	1.259	0.899	0.964	0.849	0.113
Organic Acidity, per cent	Trace	0.1	0.1	...	0.1	0.16
Sulphur, per cent	0.16	0.40	0.40	...	0.34	0.37
Steam Emulsion No., sec.	300	360	480	240	1,200+	300
Viscosity Index	86	90	90	100+	27	5

tion and is defined as the tendency to eliminate from the liquid production of the reaction everything save hydrocarbons. The alien elements, nitrogen, oxygen and sulphur, present in natural hydrocarbons and bitumens are preferentially attacked by the hydrogen so vigorously that they leave the reaction zone as the corresponding gaseous hydrides. Thus, the first and universal result of the hydrogenation process, as regards the character of the products obtained, may therefore be said to be chemical purity. A hydrogenated oil is always a very near approach to a chemically pure hydrocarbon mixture.

The second characteristic reaction is that of stabilization. The hydrocarbons that emerge from the hydrogenation process are by the very nature of the process in all cases chemically stable to a marked degree. Stability is related to, but should not be confused with, chemical saturation or carbon to hydrogen ratio. From the engineer's standpoint stability is measured by actual resistance to chemical change in storage and use, which is character of stability meant here.

The third characteristic reaction is that of homogenizing, by which is meant the tendency to produce a mixture of a more-homogeneous nature than the raw material by the preferential reformation of the more-complex molecules present. A hydrogenated oil is in general characterized by complete freedom from the extremely complex structures of the asphaltic and resinous or gummy type and relative freedom from the more heavy and complex of the viscous fractions.

These three characteristic effects of hydrogenation treatment, purification, stabilization and homogenization, are highly desirable and their attainment would be in itself of interest to the engineer as offering the promise of a generally higher level of quality for motor-fuel and lubricating oil. However, the effects referred to are secondary rather than primary. The most important properties of motor-fuels and lubricants are those resulting from the chemical structure of the prevailing type of hydrocarbon present in the mixture. Petroleum products, such as gasoline and lubricating oil, are, of course, essentially hydrocarbons but the range of molecular structures extends from the straight-chain paraffin-type on the one hand to the aromatic type on the other, together with almost infinite possibilities for modifications and combinations of the two types. Each basic type possesses recognized advantages both for fuel and lubricants. In general the paraffinic types are advantageous for lubricants while the naphthenic types are preferred for gasoline for use in Otto-cycle engines, although in the commercial production of fuels and lubricants difficulties are encountered which enforce compromise. Paraffinic lubricants as commercially produced give greater and more-objectionable carbon deposits than do naphthenic lubricants, while naphthenic lubricants usually give higher consumption and have characteristically a much-greater change of viscosity with a change of temperature. In producing naphthenic gasolines the result is usually a less-pure and less-stable product than the paraffinic gasolines but one that is decidedly superior in antiknock tendency. Crudes that yield paraffinic lubricants seldom, if ever, yield antiknock gasoline.

The possibilities that the hydrogenation process offers of reforming the molecular structure of petroleum hydrocarbons along directed lines to obtain products of the so-called paraffinic or naphthenic type have presented an opportunity to avoid these compromises.

The following data present the actual properties and performance characteristics of hydrogenated gasolines and lubricating oils as tested by the fuel and lubrication laboratories of the Standard Oil Development Co.

Hydrogenated Lubricating Oils

Table 1 gives the properties of the hydrogenated and comparative oils used in a series of tests on a White motor-truck engine. In this table *M* and *N* designate high-grade commercial, paraffin-base, premium-price lubricants, both widely sold and advertised. Oil *O* is a commercial straight Pennsylvania product, while oils *P* and *Q* refer to commercial oils from Gulf Coast naphthenic-base stocks, *P* being widely distributed throughout the Country, while *Q* is distributed mostly along the Atlantic seaboard. Table 2 presents similar data for the oils used in a series of tests on a heavy-duty Mack motor-truck engine. Here oils *A*, *B*, *C* and *D* are all premium-price products; *A* being from straight Pennsylvania paraffin-base crude and *B* and *D* from mixed paraffin-base stocks. Oil *C* is a product from mixed-base crude but containing more of the naphthenic type of hydrocarbons. Table 3 gives a comparison of hydrogenated oils with lubricants made from the same crudes by the most uptodate normal refining methods.

A study of Tables 1, 2 and 3 shows that the hydrogenated oils are in general equal, or superior, to all others in the relationships that are the usual indications of quality. In general, the gravity of the hydrogenated oils of a given viscosity at 210 deg. fahr. is high. Their flash and fire points are higher than those of any other oils. Pour test in both hydrogenated oils and natural products depends almost wholly on the nature of the stock and the extent of dewaxing. Without excessive finishing the hydrogenated oils are of high color.

TABLE 2—PROPERTIES OF OILS USED IN MACK MOTOR-TRUCK ENGINE-TESTS

Oil	Hydrogenated *M*	Hydrogenated *C*	*A*	*B*	*C*	*D*
Gravity, American Petroleum Institute deg.	29.5	27.3	28.4	22.9	21.5	24.9
Flash Point, deg. fahr.	485	460	420	415	415	425
Fire Test, deg. fahr.	560	540	470	485	475	485
Viscosity at 100 Deg. Fahr., Saybolt sec.	478	523	491	575	603	492
Viscosity at 210 Deg. Fahr., Saybolt sec.	63	62	66	60	60	61
Pour Test, deg. fahr.	20	0/No	10	10	0/No	30
Color (Robinson)	19¼	2½	2¾	¾	6½	1¼
Conradson Carbon-Residue, per cent	0.027	0.065	0.810	0.277	0.276	0.482
Organic Acidity, per cent	Trace	Trace	Trace	0.07	0.05	0.06
Sulphur, per cent	0.050	0.118	0.120	0.340	1.448	0.350
Steam Emulsion No., sec.	90	540	210	180	120	510
Viscosity Index	100	84	108	58	50	87

TABLE 3—COMPARISON OF HYDROGENATED AND NORMAL OILS FROM SAME CRUDES

	Mid-Continent		Colombia	
	Normal	Hydrogenated	Normal	Hydrogenated
Gravity, American Petroleum Institute deg.	24.9	29.5	22.7	27.3
Flash Point, deg. fahr.	415	485	410	460
Fire Test, deg. fahr.	490	560	475	540
Viscosity at 100 Deg. Fahr., Saybolt sec.	530	478	510	623
Viscosity at 210 Deg. Fahr., Saybolt sec.	62.5	63	55	62
Pour Test, deg. fahr.	25	20	0/No	0/No
Color (Robinson)	2¾	19¼	3¾	2½
Conradson Carbon-Residue, per cent	0.482	0.065	0.186	0.065
Organic Acidity, per cent	0.064	Trace	Trace	Trace
Sulphur, per cent	0.39	0.05	0.78	0.19
Viscosity Index	82	100	35	84

The Conradson carbon-residue is always low, often lower than any existing oils of equal viscosity and always lower than existing oils of equal viscosity and paraffinic nature. As mentioned earlier the hydrogenation process removes sulphur and oxygen, thus giving these products a low sulphur and organic acidity content. The changes in viscosity with a change in temperature as measured by the viscosity index is very good and where desired may be made equal to the best. The term "viscosity index" used in these tables was devised by Dean and Davis[1] and indicates the viscosity-temperature characteristics of the lubricating oil. For example, paraffinic oils such as Pennsylvania have a viscosity index of about 100, and Coastal oils a viscosity index of from 0 to 20. Thus, from the ordinary laboratory inspection, satisfactory performance could be expected for the hydrogenated oils. Two series of tests reported below show that this expectation was completely borne out.

White Motor-Truck Engine-Tests.—The White motor-truck engine-tests were made on the Model GRB which has four cylinders of 4¼ x 5¾ in. and was equipped with an OE-2 Stromberg carbureter and a ZR-4 Robert Bosch magneto. Engine power was measured with an electric cradle dynamometer; gasoline consumption, by laboratory burette apparatus; temperatures of air, water, oil, crankcase, fuel and air-fuel mixture, by thermocouples and thermometers; exhaust-gas analyses, by a bubble-type Orsat; spark-advance, by a neon-tube indicator; oil level, by a special laboratory-type level-gage; speed, both by a Hasler tachometer and by a positive revolution-counter and stop-watch; intake-manifold depression and exhaust back pressure, by special manometers; and air condition, by barometer and hygrometer. A special throttle-setting device was used to insure positive settings. Carbureter-air temperatures were held at 100 deg. fahr. plus or minus 2 deg. with an automatic electric-heater, while outlet-water temperatures were also controlled automatically at 185 deg. fahr.

The engine was put in first-class condition by removing carbon deposits; grinding valves; washing down the crankcase, valve chambers and other parts; installing new spark-plugs having an 0.025-in. gap, and setting the valve tappets with clearances of 0.008 and 0.010 in. A charge of 20 lb. of the oil to be tested was introduced into the crankcase, the oil-level gage being calibrated at the same time. The engine was then started and brought rapidly to the following operating conditions: (*a*) three-quarter load at 1400 r.p.m., (*b*) outlet water at 185 deg. fahr., (*c*) carbureter air at 100 deg. fahr., (*d*) 28-deg. spark-advance and (*e*) room temperature 70 deg. fahr.

The test was run in 50 cycles of 1 hr., as follows:

(1) 50 min. with conditions as above, data being taken at the 25 and 50-min. marks
(2) 10 min. idling at 450 r.p.m. with a beam load of 25 lb.

At the end of each test the crankcase was drained while hot, after which it was removed and the stray oil collected. The inside of the engine and the crankcase were then washed down with kerosene, after which the bearings and cylinder-walls were sprayed with the next oil to be tested. The cylinder-heads were removed, the carbon collected, valve gum removed and the valves then reground. The engine was then assembled and prepared for the next test.

The first and, thereafter, every third oil tested was a hydrogenated oil, identified as Hydrolube 75, which was used as the reference oil. The frequent runs on this oil served to give a truer comparison with the other oils tested by giving an index of the engine changes occurring as the tests progressed. The comparisons are made by referring the oils in question to the curve connecting the reference-oil points.

The interesting results of this series of tests are given in Table 4 and plotted in Fig. 1. The carbon deposition of the combustion-chamber and the oil consumption are given in terms of percentages either side of the Hydrolube reference line. The fact will be no-

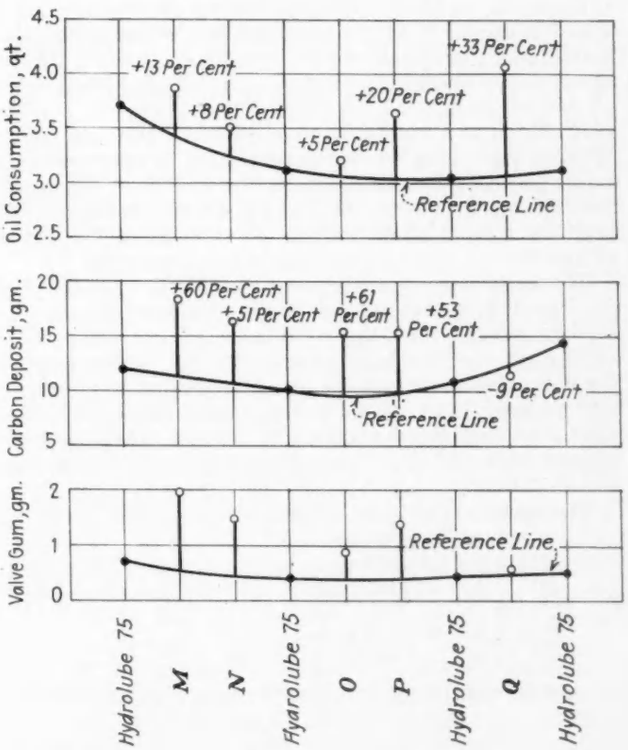


FIG. 1—COMPARATIVE 50-HR. TESTS OF HYDROGENATED AND NATURAL LUBRICATING-OILS ON A WHITE MOTOR-TRUCK ENGINE

These Tests, Which Were Made on a Four-Cylinder Engine, Indicate That, with a Conventional Low-Speed Engine Which Does Not Develop Excessive Crankcase-Oil Temperatures, the Lubricant Produced by the Hydrogenation Process Had a Lower Oil-Consumption than Paraffin-Base Pennsylvania Oils and a Carbon Deposit That Was Comparable with That of Coastal Stocks

[1] See *Metallurgical and Chemical Engineering*, October, 1929, p. 618.

TABLE 4—RESULTS OF WHITE MOTOR-TRUCK ENGINE-TESTS

Oil	Oil Consumption as Compared with Hydrolube, Per Cent	Carbon in Engine as Compared with Reference Oil, Per Cent	Valve Gum in Excess of Hydrolube Reference-Oil, Gm.
Hydrolube 75	100	100	0.0
M	112	160	1.3
N	108	151	0.9
O	105	160	0.5
P	120	146	0.9
Q	133	91	0.0

ticed that, as regards oil consumption, the Hydrolube was better than any of the other oils tested, these being representative of the best grades available today. The carbon deposited by the Hydrolube was less than that of any of the other oils except one of the Coastal naphthenic type, which had a high oil-consumption. The weight of gum deposited on the valves was lowest with the Hydrolube and the same Coastal oil. These results indicate that, with a conventional low-speed engine which does not run excessive crankcase-oil temperatures, the Hydrolube on the whole showed an improvement over the natural oils. Its performance may be characterized as follows: consumption lower than the best paraffin-base Pennsylvania lubricants and carbon deposit in the engine comparable with that obtainable with Coastal stocks. In general, the carbon deposit was proportional to Conradson carbon-residue.

Mack Motor-Truck Engine-Tests.—Because of the difficulty in satisfactorily lubricating heavy-duty high-speed motorcoach engines, we decided to run a series of tests under abnormally severe conditions on a 3⅜ x 5-in. six-cylinder engine of this type. To make these tests as severe as desired the engine was placed in a room maintained at a constant temperature of 100 deg. fahr.; the fan was removed from the engine to eliminate this upper crankcase cooling; no cooling provision was made for the oil in the lower crankcase; and to aggravate both oil consumption and carbon formation the lower of the two oil rings on the piston was removed.

The auxiliary apparatus was practically the same as for the White motor-truck engine-tests previously described except that the conditions of operation were altered to the following schedule: (*a*) Three-quarter throttle, the setting made by horsepower readings at 1600 r.p.m.; (*b*) outlet-water temperature 185 deg. fahr.; (*c*) spark-advance 24 deg.; (*d*) carbureter-air temperature 100 deg. fahr. and (*e*) room temperature 100 deg. fahr.

The speed cycles were as follows:

(1) 7 hr. at 1200 r.p.m.
(2) 8 hr. at 1600 r.p.m.
(3) 7 hr. at 1400 r.p.m.
(4) 8 hr. at 1600 r.p.m.
(5) 7 hr. at 1800 r.p.m.
(6) 13 hr. at 1600 r.p.m.

TABLE 5—RESULTS OF MACK MOTOR-TRUCK ENGINE-TESTS

Oil	Oil Consumption as Compared with Hydrolube, Per Cent	Carbon in Engine as Compared with Reference Oil, Per Cent	Valve Gum in Excess of Hydrolube Reference-Oil, Gm.
Hydrolube *C*	100	100	0.0
Hydrolube *M*	75	98	0.0
A	145	137	0.3
B	106	136	3.4
C	105	105	2.2
D	167	117	1.4

Each hour of the above speed cycles was run for 50 min. at the given speed followed by 10 min. idling at 400 r.p.m. with a beam load of 10 lb.

As in the White motor-truck engine-tests the first oil and every second or third oil thereafter was a hydrogenated oil, designated as Hydrolube 62 and made from Colombian crude. All comparisons between oils are made by reference to their position to the base line connecting the reference-oil points. In this way engine changes between tests are compensated.

Results

Table 5 shows oil consumption, carbon formation within the engine and gum formation on the inlet valves. Fig. 2 shows these same results plotted. The

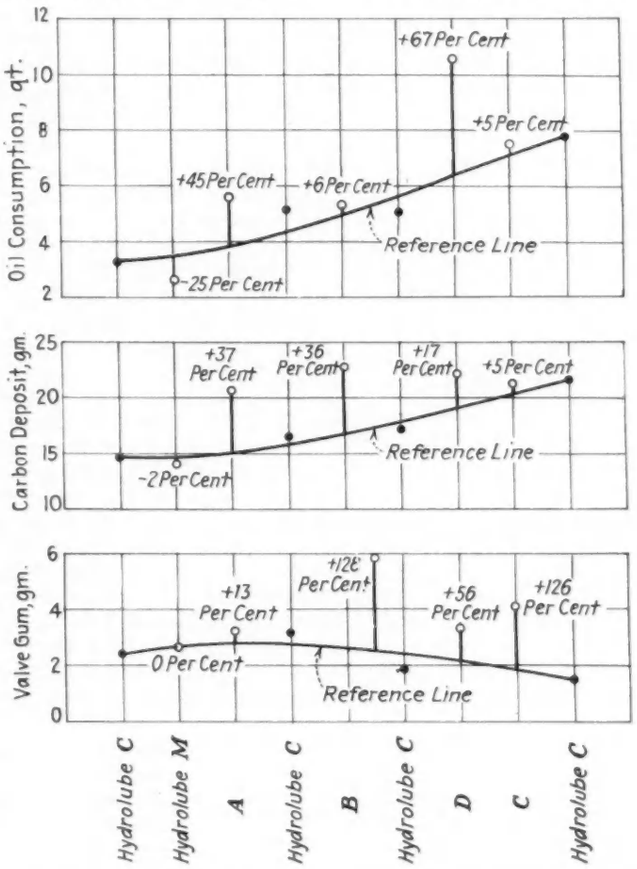


FIG. 2—SIMILAR TESTS ON A MACK MOTOR-TRUCK ENGINE

The Engine in This Case Had Six Cylinders and the Test Conditions Were Abnormally Severe. As in the Other Series of Tests the Performance Characteristics of the Hydrogenated Products Were Superior in All Respects to Those of the Other Oils Tested

two hydrogenated products show performance characteristics superior in all respects to those of the other oils tested.

These last tests taken in connection with the tests on the White motor-truck engine indicate the superiority of the hydrogenated products both for conditions of moderate and severe service. In the Mack motor-truck engine-tests, where conditions were exceptionally severe, the only oils tried other than the Hydrolubes were those known to be of the highest quality, since oils of lower quality under these conditions would have shown excessive consumption. A noteworthy feature, therefore, is that, under these extreme conditions and in

TABLE 6—ESTIMATED SALES IN THE UNITED STATES OF GASOLINE OF VARIOUS ANTIKNOCK VALUES

Sales, Per Cent	Antiknock Value, Octane No.
6	Below 43
10	43 to 57
62	57 to 66
6	66 to 73
10	73 (Ethyl Standard)
6	Above 73

comparison with high-grade natural products, not only did the low oil-consumption of Hydrolubes show up to better advantage than under the more-moderate operating-conditions in the White motor-truck engine-tests but also that the condition of the engine with the

TABLE 7—PROPERTIES OF HYDROGENATED ANTIKNOCK GASOLINES USED AS BLENDING STOCK

Gravity, American Petroleum Institute deg.	45.1	47.2	45.7
Initial-Distillation Point, deg. fahr.	92	95	106
Percentage Distilled at			
140 deg. fahr.	14.0	12.0	..
158 deg. fahr.	20.0	18.0	9.0
212 deg. fahr.	34.0	36.0	26.0
284 deg. fahr.	51.0	58.0	55.0
356 deg. fahr.	73.5	78.0	90.0
90-Per Cent Point, deg. fahr.	384	384	356
End Point, deg. fahr.	410	422	406
Recovery, per cent	99.0	99.0	99.0
Octane No.	82.8	88.0	90.0
Dissolved Gum, gm.	19.6	3.9	5.2
Induction Period, hr.	2.0	1.1	1.6
Color (Robinson)	23	22	23
Sulphur, per cent	0.017	0.016	0.020

hydrogenated products, as shown by carbon formation, gum on inlet valves, wear and general inspection, was the better.

Hydrogenated Gasolines

A recent estimate of gasolines marketed throughout the Nation plotted on the basis of knock rating against percentage sold is shown in Fig. 3. This same information is given in Table 6. This clearly illustrates why the development of higher-efficiency, higher-compression automotive equipment has been so much delayed. Hydrogenated gasolines have been made with a knock rating up to 95 octane number and with blending characteristics as good as chemically pure benzol. Fig. 4 shows the effect of blending various percentages of hydrogenated gasolines of 83.2, 87.7 and 90.4 octane

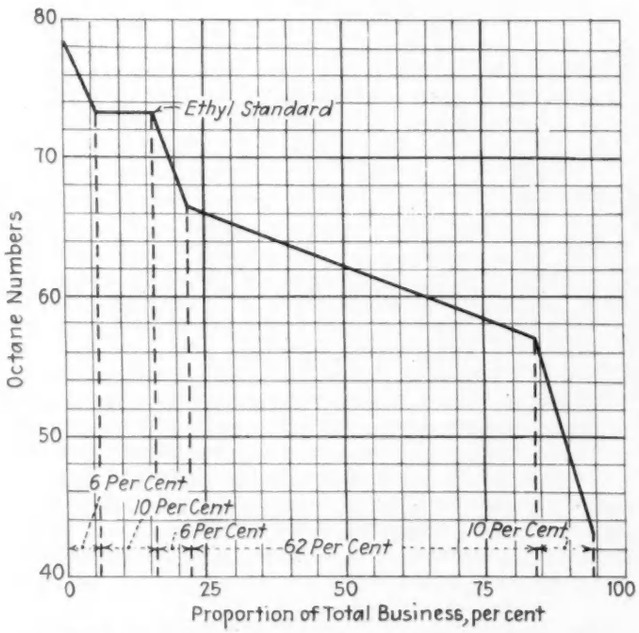


FIG. 3—SURVEY OF GASOLINE SALES IN THE UUITED STATES ON THE KNOCK-RATING BASIS

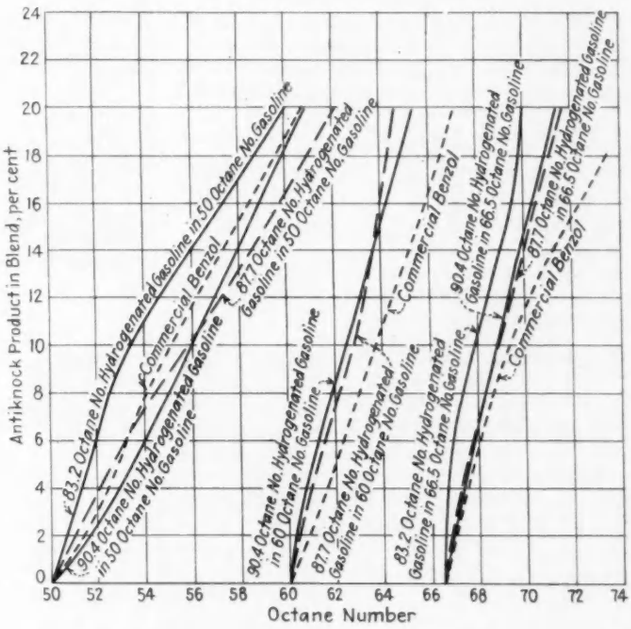

Antiknock Product in Blend, per cent
Octane Number
83.2 Octane No. Hydrogenated Gasoline in 50 Octane No. Gasoline
90.4 Octane No. Hydrogenated Gasoline in 50 Octane No. Gasoline
Commercial Benzol
87.7 Octane No. Hydrogenated Gasoline in 50 Octane No. Gasoline
90.4 Octane No. Hydrogenated Gasoline in 60 Octane No. Gasoline
87.7 Octane No. Hydrogenated Gasoline in 60 Octane No. Gasoline
Commercial Benzol
83.2 Octane No. Hydrogenated Gasoline in 66.5 Octane No. Gasoline
90.4 Octane No. Hydrogenated Gasoline in 66.5 Octane No. Gasoline
87.7 Octane No. Hydrogenated Gasoline in 66.5 Octane No. Gasoline
Commercial Benzol

FIG. 4—EFFECT OF BLENDING VARIOUS PERCENTAGES OF HYDROGENATED GASOLINES OF OCTANE NUMBERS 83.2, 87.7 AND 90.4 AND COMMERCIAL MOTOR BENZOL INTO FUELS HAVING OCTANE NUMBERS OF 50, 60 AND 66.5

numbers into three fuels of 50, 60 and 66.5 octane numbers respectively, and the results of blending motor benzol into the same fuels are also plotted. The properties of these blending stocks are given in Table 7.

Another characteristic of these hydrogenated fuels and one which is radically different from that of the cracked naphthas is that the heavier fractions have the best antiknock qualities. A graph showing the octane numbers plotted against various distillation points of a typical cracked stock and of a hydrogenated fuel is reproduced as Fig. 5. The Otto-cycle air-cooled aviation-engine has the advantage of very light weight per horsepower delivered, with the disadvantage of using a very volatile fuel of very low flash-point. The Diesel-cycle engine has a greater weight per horsepower but a safety advantage in that a high-flash-point fuel is used. For positive fuel-injection and atomization an Otto-cycle engine cannot advantageously use present non-volatile fuels because of their severe detonating characteristics. Hydrogenation gives a high-flash fuel of extremely good antiknock value, making possible future developments of this nature, particularly in the airplane and marine fields.

Hydrogenated gasolines are also very sensitive to the addition of tetraethyl lead. Table 8 gives the octane numbers at 212 and 300 deg. fahr. of several aviation gasolines made by different processes. The quantity of

tetraethyl lead required at both 212 and 300 deg. fahr. to bring these fuels to the Army Air Corps specification of 87 octane number is also given.

Hydrogenated fuels have characteristically low sulphur-contents, the average being less than 0.03 per cent. Much controversy has arisen concerning sulphur in gasolines. Most of this experimental work has been limited to a study of engine corrosion. Insufficient results have, as yet, been reported on the effect of sulphur content on carbon deposition, of lead-sulphate deposition on exhaust valves when tetraethyl lead is used and on the gum formation in intake manifolds and on intake valves.

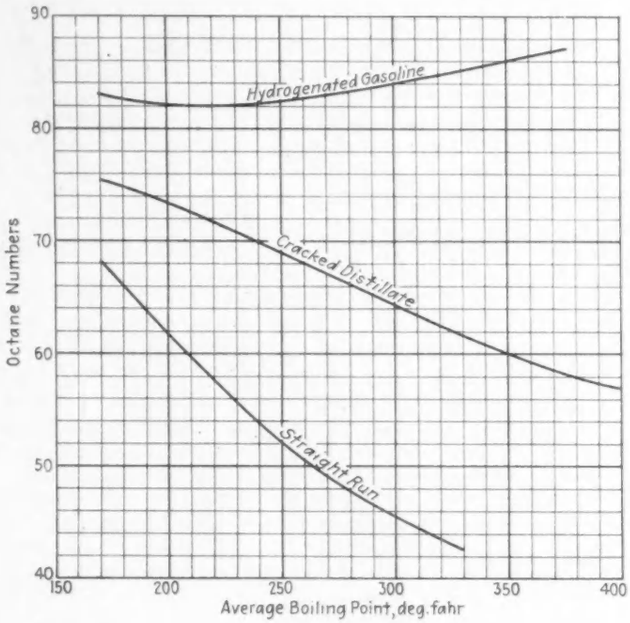


FIG. 5—ANTIKNOCK CHARACTERISTICS OF HYDROGENATED GASOLINE, STRAIGHT-RUN GASOLINE AND CRACKED DISTILLATE PLOTTED AS A FUNCTION OF THE BOILING RANGE

The properties of the blending stocks given in Table 7 show the hydrogenated fuels to have low gum-content and also by the oxygen-bomb test to be very stable.

TABLE 8—OCTANE NUMBERS OF VARIOUS AVIATION GASOLINES

Stock	Octane No. 212 Deg. Fahr.	Octane No. 300 Deg. Fahr.	Lead Required To Equal 87 Octane No., Cc. 212 Deg. Fahr.	Lead Required To Equal 87 Octane No., Cc. 300 Deg. Fahr.	Octane No. Change per Cc. of Lead at 300 Deg. Fahr.
Straight-Run California	76	76	1.6	1.5	7.3
90 Per Cent of Straight-Run California and 10 Per Cent of Benzol	79	75	1.1	1.2	10.0
Straight-Run Smackover	74	72	2.7	3.8	4.0
Vapor-Phase Cracked Texas	75	73	3.6	4.2	3.3
Hydrogenated Aviation *A*	80.4	79	0.7	0.9	9.0
Hydrogenated Aviation *B*	74.8	73.5	1.1	1.7	8.0

This bomb test consists in placing a small quantity of fuel in a gas-tight steel-bomb and subjecting it to 100-lb. pressure of oxygen. After testing the bomb for leakage it is coupled to a pressure-recording gage and placed in a steam bath. The time from maximum pressure until a drop of 5 lb. occurs is called the induction period and is a measure of the fuel's stability. A fuel that will stand up 1½ hr. under this test is exceptionally stable.

Summary

The tests here referred to show that hydrogenated lubricating-oils made from available common crudes are superior to the highest grade of natural lubricants now available to the automotive industry.

High-grade naphthenic gasolines and blending stocks are produced by hydrogenation from relatively low-grade gas-oils, these highly antiknock blending stocks having iso-octane numbers of from 90 to 95 and a blending value in commercial gasoline equal to pure benzol. They are low in gum and sulphur and are gum and color stable. They are excellent stocks for use with tetraethyl lead, since the lead susceptibility is good, being considerably better than for most cracked products.

The process of hydrogenation, when widely adopted by the petroleum industry, apparently will open up to the automotive engineer the possibility of designing engines for operating at greater compressions, higher speeds and higher temperatures, resulting in a marked gain in efficiency.

THE DISCUSSION

R. E. WILSON[5]:—I notice that the carbon residues of these oils are similar in quantity to those of Texas oils. How do they compare in character? We have made some oils which were similar to Pennsylvania oils in temperature coefficient and similar to Texas oils in the *quantity* of carbon residue, but find them similar to Pennsylvania oils in leaving a *harder* carbon residue.

Have any comparisons been made between these and ordinary hydrocarbon oils as to their oiliness?

Just as a matter of interest, I notice that Dr. Haslam indicated that Ethyl Standard corresponded to an octane number of about 73, whereas our results indicate about 74.5. I wonder which is the official rating.

A. A. LANE[6]:—Were any of the oils to which Dr. Haslam referred Gulf Pride?

DR. R. T. HASLAM:—I would rather not give the names of any of the oils. The test data were not presented with that in view. To take inspections of any oils and see how they compare with the inspections given is an easy task.

With reference to Mr. Wilson's questions, the character of the carbon residue in the hydrogenated oils follows that of the Pennsylvanias. Carbon is present in less quantity but has the characteristics of a paraffinic product. The relative merits and demerits of this type of carbon are questionable.

Oiliness Defined

To be honest, I do not know what oiliness is. That does not mean that I am not reasonably familiar with

[5] M.S.A.E.—Assistant to vice-president in charge of manufacturing, and head of development and patent department, Standard Oil Co. of Indiana, Chicago.

[6] M.S.A.E.—Mechanical engineer, Gulf Co.'s Research Department, Pittsburgh.

the literature, but other than meaning the coefficient of the static friction, I do not know how to define it. Perhaps if Mr. Wilson will tell me how to define it, I can tell him whether these hydrogenated oils have it or not. We all like to have a few words like "oiliness" behind which we can retire, and I have used the word "colloidal," and in hydrogenation work we can use the word "catalyst" for such a purpose.

I fully agree that Dr. Edgar can probably tell us better which iso-octane number of Ethyl Standard is right, but if the figure I gave is wrong, it is simply one of the places at which that particular plot is probably wrong, although we did mean to get Ethyl Standard correct on it.

MR. WILSON:—I realize that the term "oiliness" is frequently used for many purposes, but I have always defined it in my articles in the same way, and I am willing to stand back of that definition, which is,

R. E. WILSON

> Oiliness is that property of one lubricant that makes it give a lower coefficient of friction, particularly at high load and low speed, than another lubricant of the same viscosity.

R. T. HASLAM

H. C. MOUGEY

I do not know how to compare oiliness between two oils of different viscosities, but viscosity is the only property of importance in determining the coefficient of friction in fluid-film lubrication and, when we get to very high loads or very low speeds, some lubricants *do* show lower coefficients of friction than others, and those, we say, have greater oiliness.

DR. HASLAM:—From that standpoint, as far as we can see, hydrogenated lubricants are no different from the current paraffin-base lubricants, making due allowance for experimental error. We have done very little work on the oiliness of engine lubricants, feeling that only in a very few cases does it come into play.

MR. WILSON:—I agree on that as to automobile engines.

DR. HASLAM:—Most of the bearing failures we notice come, not from lack of oiliness, but from a breakdown of the oil, tending toward sludging. We had three bearings that we happened to catch, I might say, in the process of breaking down. One was completely broken down, one partly scored, and the other just about ready to score; and the mechanism of the failure seemed to be that within the clearance between the journal and the bearing the oil started to sludge. As sludging started, the clearance decreased. With decreased clearance we again got a whole chain of circumstances, the net result of which was a further decrease in oil-flow, a further increase in temperature and further sludging, so that portions of the bearing started to scurf. We had one bearing that was practically all covered with this very fine sludge, one covered with the sludge film but scurfed off here and there, and the other which was completely scored and in which seizure had taken place.

T. A. BOYD

I may generalize this by saying we think that stability, from a standpoint of preventing bearing failure in an automobile engine, is more important than oiliness.

CHAIRMAN H. C. MOUGEY[7]:—Would Dr. Haslam prefer using any particular kind of crude in making hydrogenated oils? I notice that he has used oils having a rather flat viscosity-temperature slope. Can he make them from either type of crude?

DR. HASLAM: — That comes down to a question of economics. If we have to start with a base stock that is extremely deficient in hydrogen, we have to put in more hydrogen to get the proper carbon-to-hydrogen ratio. Therefore, to start as near the goal as we can is economical, but we can certainly use a large variety of stock.

MR. LANE:—I do not believe that the extent of the tests as shown in the paper would warrant the statement that this product is superior to any lubricant now on the market.

DR. HASLAM:—I suppose that criticism is really true, because, to prove the truth of that statement, we should have to test every product, which naturally is a physical impossibility; the best thing we can do is to pick out four or five products that, in our judgment, are representative of the best in the market, and test the new product against these. Actually, all we can really say is that the product is better than those tested. Whether the latter represent the best on the market or not, I cannot say, but complete inspections of the competitive products tested are given. Any oil man can probably identify most if not all of them, or at least come very close to it.

T. A. BOYD[8]:—I should like to say a word about this subject of octane numbers that has been discussed to some extent this afternoon. That everyone should know about this means of rating fuels with respect to

[7] M.S.A.E.—Chief chemist and assistant technical director, General Motors Corp. Research Laboratories, Detroit.

[8] M.S.A.E.—Head of fuel section, General Motors Corp. Research Laboratories, Detroit.

antiknock quality is desirable, as it represents a distinct step forward. The desire is to call it octane number and not iso-octane number, as a matter of simplicity. The compound from which the name is derived is iso-octane, which is the compound of better antiknock quality or the one of higher antiknock quality. The compound of low antiknock quality is normal heptane, which is a straight-chain paraffin hydrocarbon and has a very low antiknock quality.

The difference between these two hydrocarbons is approximately 4½ or 5 compression ratios. That is to say, the difference between the limiting compression-ratio of the lower one and the limiting compression-ratio of the higher one is about 4½ or 5 ratios. This gives a means of expressing antiknock quality in terms of the percentage of the better compound in the mixture, or of the percentage of iso-octane by volume in a mixture of the two which just matches the antiknock value of the fuel in question. That quality is called the octane number of the fuel and is the first means by which everyone has been able to talk the same language in speaking of antiknock qualities of fuels.

I am not authorized to say what the octane number of Ethyl gasoline is, but since some different values have been expressed for it today, I will get right in between Dr. Haslam and Mr. Wilson and say that, to the best of my knowledge, the current octane number of Ethyl gasoline is 74.

S. P. MARLEY

W. H. GRAVES[9]:—Can a flatter viscosity curve than has been indicated be obtained by higher hydrogenation or, in other words, carrying the process farther?

DR. HASLAM:—We have obtained somewhat flatter viscosity curves than those mentioned. Offhand I cannot give the maximum viscosity index, but in general, after passing 104, 108, 110 or something like that, using the viscosity index as being the only method I know for measuring the flatness of the curve, the yield begins to go down rapidly. While I think we can go higher, I do not know that this is commercially possible at present, unless some real desirability of getting higher exists. I think, offhand and from memory only, that the highest viscosity index which I have ever seen of any lubricating oil was something around 135 or 155. That oil is much more paraffinic than any of those shown.

CHAIRMAN MOUGEY:—Are these products still in the experimental stage or are they near commercial production?

DR. HASLAM:—They are near commercial production. I think they will be on the market in the spring or summer.

M. B. COOKE[10]:—Knowing the consumption of one oil in a given engine and under a given set of conditions, could you not predict the consumption of five or a dozen other oils by simply taking the vacuum distillation at a very low pressure on all the oils? We have done some work which indicates that this is possible.

DR. HASLAM:—At low-speed low-temperature operation the consumption seems to follow the flash-point or volatility, or information we can get from a vacuum distillation. In high-speed operation it often seems to follow the viscosity of the oil at the temperature of the engine and in between we have a combination of the two. Many conditions exist where we seem to get a very exact correlation between the vacuum Engler distillation and oil consumption. However, in going to a different type of product or making new products, or again if we encounter new engine-conditions, we think that making an actual engine test rather than to use the short cut of flash-point or viscosity at the high temperature or a vacuum Engler distillation is better.

SAMUEL P. MARLEY[11]:—Dr. Haslam has shown in all tests, both for the White engine and for the heavy-duty motor-truck engine, that lower consumptions were recorded for the Hydrolubes than for any of the other lubricants used, although matched-viscosity oils at 210 deg. fahr. were employed. The consumption of a lubricating oil in an internal-combustion engine is generally accepted as being proportional or very closely related to its viscosity. Since the oils were matched at 210 deg. fahr, and still rather large variations in consumption occur for all the lubricants used, and in favor of the Hydrolubes, I should like to ask if Dr. Haslam has made any viscosity comparisons of the lubricant at, say, 250 or 300 deg. fahr. From the data presented one might with reason assume that a difference in viscosities at the higher temperatures, which conform more nearly to engine-operating conditions, would be found.

DR. HASLAM:—That oils of equal viscosities at 210 deg. fahr. do not have equal consumptions is generally known and admitted. The consumption depends on operating conditions. Under some engine conditions, particularly when pumping occurs, the consumption is largely proportional to the viscosity of the oil at the engine temperature. Under less severe conditions the consumption is likely to be controlled more by the volatility of the oil than by its viscosity at engine temperatures.

[9] M.S.A.E.—Chief metallurgist, Packard Motor Car Co., Detroit.

[10] Director of research department, Tide Water Oil Co., Bayonne, N. J.

[11] M.S.A.E.—Resarch engineer in petroleum technology, Mellon Institute of Industrial Research, Pittsburgh.

A Survey of Current Automobile and Bus Fuel-Line Temperatures[1]

By Oscar C. Bridgeman[2] and Hobart S. White[3]

Annual Meeting Paper

PREVIOUS work on vapor lock at the Bureau of Standards under the auspices of the Cooperative Fuel Research Steering Committee has resulted in considerable information regarding the relation between the properties of gasolines and vapor lock and between fuel-line design and vapor lock. Satisfactory means have been developed for predicting the conditions under which vapor lock would occur with a given fuel, but no extensive information has been available on the gasoline temperatures existing in the fuel feed lines of automotive equipment. This has made it very difficult for the refiner to supply satisfactory fuels for current automotive equipment.

The present report includes temperature data obtained at several points in the fuel feed systems of 27 automobiles and 8 buses under various operating conditions. At 40 m.p.h., the maximum temperature observed in the fuel systems of the passenger-cars studied was 73 deg. fahr. above atmospheric temperature, while the average temperature at the fuel-pump or vacuum-tank outlet for the 27 cars was 41 deg. above that of the atmosphere. During idling after a 40-m.p.h. run, the temperature increased still further by as much as 20 deg. The fuel-line temperatures found in the buses investigated were, on the average, slightly lower than those found in the passenger-cars.

The results obtained reflect seriously on the design of automobile fuel-feed systems, and certain suggestions are made regarding improvement in design on the basis of the experimental data. It is considered that the introduction of fuel-pumps has been more responsible for the widespread occurrence of vapor lock than has any increase in the average volatility of fuels during the last two years, and therefore it behooves the automotive engineer to do his part in keeping the fuel system as cool as possible. With some care and thought on the part of the designer, it is felt that the gasoline temperature at the fuel-pump can be materially reduced.

THE frequency of occurrence of vapor lock in automobile, bus, truck and airplane fuel systems has markedly increased during the last few years. The petroleum refiners have blamed the designers of automotive equipment, and vice versa, both groups being correct. Such a situation demands cooperative investigation and, in fact, for the past two years a cooperative investigation of this nature has been in progress, through the medium of the Bureau of Standards. Much has been learned in this work regarding the relation between fuels and vapor lock, and between fuel-line design and vapor lock. Concrete suggestions have resulted regarding control of the vapor-locking tendencies of fuels and regarding improvements in fuel-line design. Satisfactory means have been developed for predicting the conditions under which vapor lock would occur with a given fuel, but no extensive information has been available on the conditions which exist in the fuel feed lines of automotive equipment. This has made it very difficult to supply satisfactory fuels for current automotive equipment.

During the spring and early summer of 1930, vapor lock caused so much trouble that immediate action was imperative. Accordingly, the Cooperative Fuel Research Steering Committee requested the Bureau to concentrate its efforts on amassing fuel-temperature data in the fuel feed lines of automobiles, buses and trucks and to enlist the cooperation of as many individuals and organizations as could be interested in the project. This report covers the information obtained on automobile and bus fuel-feed systems, which will be treated separately in the order named. Some information was also obtained on trucks, but is being withheld until a more comprehensive set of results has been secured. It is planned to present analogous data on airplanes at the National Aeronautic Meeting of the Society in April.

About half of the data on automobiles were obtained by the Bureau of Standards; about one-sixth by the General Motors Corp.; about one-sixth by the Chrysler Corp.; and about one-sixth by the Standard Oil Development Co., the Central Illinois Public Service Co. and the Armour Institute of Technology. All of the bus data were obtained by the Bureau of Standards on buses furnished specially for this purpose by the Public Service Coordinated Transport (New Jersey). The assistance and cooperation of these organizations is gratefully acknowledged, as is also that of a number of dealers who very kindly loaned some of the cars used in these tests.

Instrumentation

Previous experience by the Bureau in connection with temperature measurements in airplane fuel systems had indicated the difficulty of obtaining an instrument for use with thermocouples which was on the one hand sufficiently sensitive and on the other hand sufficiently stable and rugged to withstand the vibration. Flight tests in airplanes, however, indicated that use of a re-

[1] Publication approved by the Director of the Bureau of Standards, Department of Commerce.

[2] S.M.S.A.E.-Research associate, Bureau of Standards, City of Washington.

[3] Junior physicist, Bureau of Standards, City of Washington.

sistance thermometer in conjunction with a direct-reading ohmmeter was entirely satisfactory, giving both the desired sensitivity and the desired stability. This type of instrumentation was therefore used by the Bureau in all of its measurements on automobiles and buses.

Interchangeable resistance-thermometers were made which fitted into specially constructed pipe-fittings, inserted in the fuel feed line. A detailed diagram of the thermometers and fittings is shown in Fig. 1. This type does not represent good practice for the construction of resistance thermometers for precision measurements but was adequate for the present purpose. In making the thermometers, No. 40 silk-covered nickel wire was soldered to one end of a length of No. 16 flexible insulated copper wire, and was then wound back around the copper to form a coil approximately 1/8 in. in diameter and 5/8 in. long, having a resistance of approximately 40 ohms. The loose end of the nickel wire was soldered to another length of No. 16 copper wire, and the coil was inserted into a thin-walled copper tube, closed at one end. Molten shellac was then poured around the top of the coil, fixing it in position and preventing the entrance of moisture. These thermometers were interchangeable, so that any one could be used in each of the fittings. The ohmmeter did not read temperatures directly, so that each thermometer was calibrated in conjunction with the ohmmeter, thereby giving a temperature-ohmmeter-reading calibration-curve over the temperature range of interest. The precision of the temperature-measuring equipment was 0.5 deg. cent. (0.9 deg. fahr.).

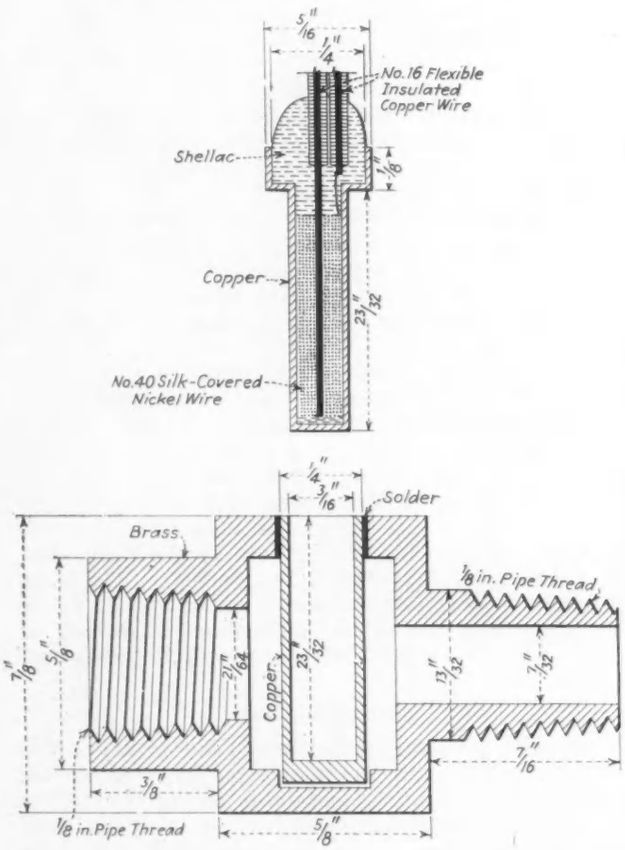


FIG. 1—SECTIONAL VIEWS OF THE RESISTANCE THERMOMETER AND PIPE-FITTING

The diagram of the fuel-line fitting in Fig. 1 is self explanatory. While the arrangement of threads indicated was found most generally useful, some fittings were made with internal threads on both ends. When in use, the thermometer was usually taped in place in the fitting.

Some of the cooperating organizations found that thermocouples could be satisfactorily used in conjunction with a potentiometer if the latter was very carefully mounted. This has also been the recent experience of the Bureau if the roads are not extremely rough, but great care must be taken to insulate the indicating instrument from vibration. Accordingly, while all of the Bureau measurements were obtained with resistance thermometers, some of the data by the cooperating laboratories were secured with thermocouples.

The points at which temperature data were obtained in automobile fuel systems were as follows:

(1) *Vacuum-Tank Systems.*—Fuel-tank outlet, vacuum-tank inlet, vacuum-tank outlet, carbureter inlet, and carbureter bowl in some instances.

(2) *Fuel-Pump Systems.*—Fuel-tank outlet, fuel-pump inlet, fuel-pump outlet, carbureter inlet, and carbureter bowl in some instances

(3) *Gravity-Feed Systems.*—Tank outlet, sediment-bowl outlet and carbureter inlet

Similar points were used in bus fuel-feed systems, and in those cases where the system had two carbureters measurements were made at the inlet to each. In every run with both automobiles and buses the outside-air temperature was recorded.

Automobile Fuel Lines

In most of the tests constant-speed runs at 20, 30 and 40 m.p.h. were made. In some of the tests, constant speeds of 25, 50 and 60 m.p.h. and faster were employed. Each constant-speed run was of such duration that the temperature at each point reached a maximum and remained constant. A 40-mile run was found to be sufficient in all cases, while in some of the runs a shorter distance was sufficient. At the completion of each run, the car was drawn over to the side of the road and measurements made while the engine was idling with the gears in neutral. The idling period was of such duration that the temperature at each point reached a maximum and then dropped.

With about half of the cars, a run up a 6-mile hill was made at the maximum speed permitted by the steepness and by the curvature of the turns, which was about 30 to 40 m.p.h. The temperatures were recorded at stated intervals during the climb, and the maximum values while idling in neutral at the top of the hill were noted. A profile of this hill is shown in Fig. 2.

Data are presented on 27 cars which are described in Table 1. Of this number, 3 have vacuum-tank systems, 23 have fuel-pump systems and 1 has a gravity-feed system. There are 4 four-cylinder cars, 13 six-cylinder cars and 10 eight-cylinder cars. One of the cars is a 1928 model, 7 are 1929 models, 8 are 1930 models and 11 are 1931 models. Two of the cars have V-type engines. Where the same letter is used to designate two or more cars it indicates that they are of the same make and general design.

The method adopted in recording the experimental data is illustrated in Fig. 3 for car *K*. The solid lines

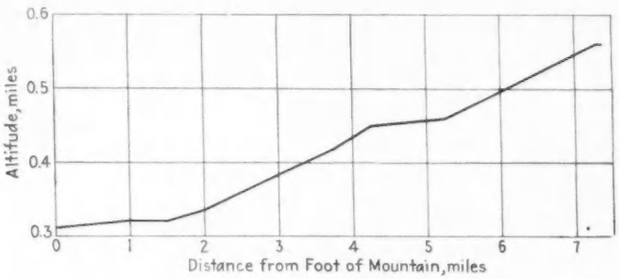


FIG. 2—PROFILE OF MOUNTAIN ROAD USED IN TEST RUNS

represent the maximum temperatures reached under the designated test-conditions and the dotted lines represent the maximum temperatures reached during idling in neutral after each test run. In order to make possible a more legitimate comparison between the data on different cars and on the same car when run on different days, the increases in fuel temperatures at each point above that of the atmosphere were evaluated. These temperature increments for each of the constant-speed runs on car *K* are shown in Fig. 4, in which the temperature increments are plotted against the speed.

TABLE 1—DESCRIPTION OF TEST CARS

Car	Year	Fuel System	No. of Cylinders
A	1928	Pressure	6
A1	1929	Pressure	6
B	1929	Pressure	6
B1	1929	Pressure	6
C	1929	Vacuum	6
D	1929	Pressure	8
E	1929	Pressure	6
E1	1930	Pressure	6
F	1929	Vacuum	6
G	1930	Gravity	4
H	1930	Pressure	8
I	1930	Pressure	8
J	1930	Pressure	8
K	1930	Pressure	8
L	1930	Vacuum	8
M	1930	Pressure	4
M1	1931	Pressure	4
M2	1931	Pressure	4
N	1931	Pressure	6
N1	1931	Pressure	6
O	1931	Pressure	6
P	1931	Pressure	8
Q	1931	Pressure	8
R	1931	Pressure	6
R1	1931	Pressure	6
S	1931	Pressure	8
T	1931	Pressure	8

A summary of the data on the 27 cars is given in Table 2 for temperatures at the main-tank outlet, the fuel-pump or vacuum-tank inlet, the fuel-pump or vacuum-tank outlet and the carbureter inlet or bowl. All fuel temperatures are recorded as temperature increases above atmospheric. The temperature increments at speeds of 20, 30, 40, 50 and 60 m.p.h. are listed in the first five columns in each group. The sixth column gives the temperature increments above atmospheric during idling after the 40-m.p.h. runs, and the seventh column in each group gives the maximum temperature increments during the climb up the 6-mile mountain. The last column in the table indicates the average atmospheric temperature during the runs on each car.

The average of the data in every column is given at the bottom. Three things should be kept in mind in interpreting these averages. First, more data have been obtained on cars at some speeds than at others; second, values for temperatures at the fuel-pump or vacuum tank have been averaged, regardless of the type of fuel system; and third, no differentiation has been made between temperatures in the carbureter inlet and the carbureter-float bowl. In connection with the first point, no other system of averaging seems desirable. With regard to the second, temperatures at the fuel pump and vacuum tank are equally significant from the standpoint of vapor lock. As for the third point, it is not considered that temperatures at the carbureter are very significant at present in connection with vapor lock, with the possible exception of V-type engines having the carbureter mounted between the rows of cylinders.

These averages might be taken as representative of an average make of car and are shown graphically in Fig. 5 for the constant-speed runs, assuming a fuel-pump system. It is to be noted that the temperatures are essentially independent of speed, although there is a slight indication of an increase in temperature with increasing speed.

Confining attention to the values at 40 m.p.h., the average, maximum and minimum observed temperature-increments above atmospheric temperature for the various fuel-system locations are listed in Table 3. It is seen that the temperature of the gasoline in the fuel tank is considerably above that of the atmosphere, the difference being 18 deg. fahr. on the average. In going from the fuel tank to the fuel-pump or vacuum-tank inlet, the gasoline is heated another 11 deg. Passing

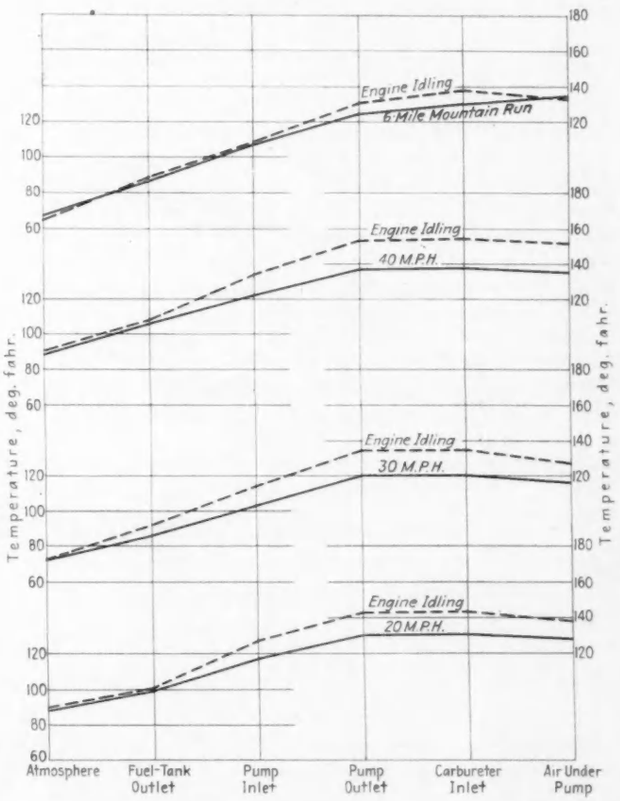


FIG. 3—EXPERIMENTAL DATA FROM TESTS OF CAR *K*

through the pump or vacuum tank increases the temperature still another 12 deg. on the average, while there is little change between the pump or vacuum-tank outlet and the carbureter. Of the 41-deg. average rise in temperature above that of the atmosphere, 18 deg. occurs in the fuel tank, 11 deg. up to the engine compartment and 12 deg. in either the pump or the vacuum tank. Also there is a still further rise of 14 to 19 deg. during idling after a 40-m.p.h. run, making the total increase about 60 deg. fahr. above the atmospheric temperature. It is interesting to note that the average increase in temperature during the climb up the 6-mile hill is approximately the same as that during idling after the 40-m.p.h. run.

Interpreting these temperature data in terms of gasoline vapor-pressures and vapor lock, it means that a gasoline must have a Reid vapor-pressure of less than 8 lb. per sq. in. at 100 deg. fahr. if vapor lock is to be avoided when driving at 40 m.p.h. in this hypothetical average make of car with an atmospheric temperature of 90 deg. fahr. If protection against vapor lock is desired on idling after a long run with this average make of car at 90-deg. atmospheric temperature, the gasoline used must have a vapor pressure of less than 6 lb. per sq. in. It should be emphasized that the foregoing vapor-pressure values give protection only in cars which have fuel-line temperatures lower than the average observed in this work. Almost half of the cars listed in the tables might be expected to give vapor-lock trouble on 8-lb-per-sq-in. gasoline at 40 m.p.h. and 90-deg. atmospheric temperature, and on 6-lb-per-sq-in. gasoline on idling after such a run.

The values given in the last paragraph are based on the average temperatures obtained by giving equal weight to each make of car. However, there are several

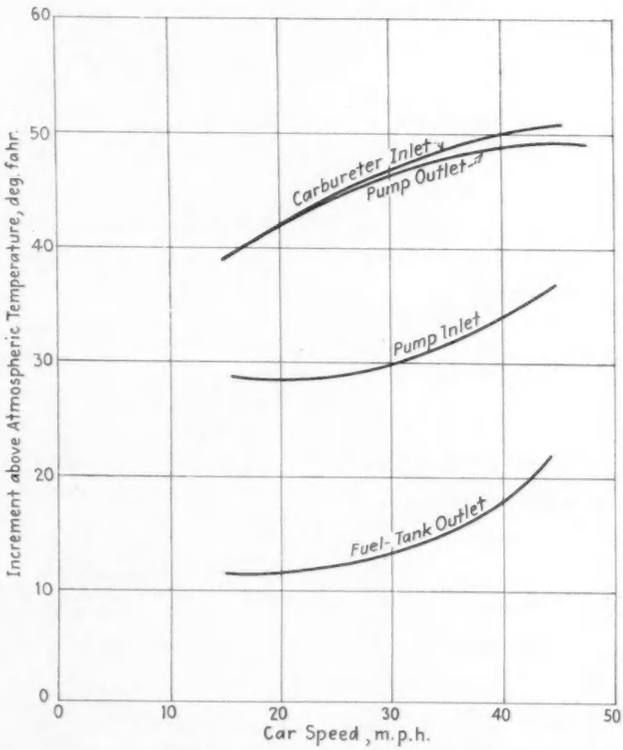


FIG. 4—EFFECT OF SPEED ON FUEL-LINE TEMPERATURES OF CAR *K*

TABLE 2—FUEL-LINE TEMPERATURE INCREMENTS ABOVE ATMOSPHERIC TEMPERATURE OBSERVED IN TESTS, DEG. FAHR.

Car	Fuel-Tank Outlet: Speed, M.P.H. 20	30	40	50	60	Fuel-Pump or Vacuum-Tank Inlet: Idle[a]	Climb[b] 20	30	40	50	60	Fuel-Pump or Vacuum-Tank Outlet: Idle[a]	Climb[b] 20	30	40	50	60	Carbureter Inlet: Speed, M.P.H. Idle[a]	Climb[b] 20	30	40	50	60	Average Atmospheric Temperature	Car
A	18	21	22	22	22	26	..	..	..	..	..	40	..	..	..	..	..	46	..	..	..	..	..	42	..	..	..	90	*A*
A1	18	21	22	22	22	28	..	30	40	44	..	57	..	48	52	53	49	67	..	45[c]	52[c]	56[c]	56[c]	61[c]	..	..	..	80	*A1*
B	9	9	10	..	..	13	19	18	18	17	..	34	26	20	20	22	22	41	48	27	27	26	..	61	37	..	..	75	*B*
B1	11	9	8	9	12	11	..	10	10	10	12	15	11	..	22	22	21	47	..	31[c]	28[c]	26[c]	28[c]	59[c]	..	..	..	80	*B1*
C	12	13	13	..	..	20	20	21	20	..	..	52	38	24	24	24	24	40	38	35	35	35	35	45	50	..	..	70	*C*
D	21	19	18	18	20	22	..	39	37	36	36	56	..	53	49	47	47	57	..	58[c]	53[c]	50[c]	51[c]	58[c]	..	..	..	70	*D*
E	12	15	18	22	27	..	..	24	36	39	41	48	..	33	42	48	51	60	..	24[c]	30[c]	35[c]	39[c]	42[c]	37[c]	..	..	55	*E*
E1	24	26	29	..	..	29	36	36	40	42	..	54	51	39	43	44	..	64	51	37	39	40	..	..	64	49	..	75	*E1*
F	16	13	11	..	..	21	25	28	29	28	25	..	..	56	41	39	39	61	53	40	39	35	..	..	69	55	..	80	*F*
G	18	18	21	..	..	21	28	..	..	..	..	..	..	..	..	29[d]	31[d]	63[d]	41[d]	39	41	44	..	..	68	57	..	80	*G*
H	13	18	20	..	..	21	28	..	41	44	49	..	..	62	52	60	68	90	66	55	58	60	..	..	74	61	..	65	*H*
I	..	18	26	28	29	34	..	..	25	32	33	30	38	..	..	..	34	56	..	..	40[c]	46[c]	46[c]	64[c]	..	..	..	85	*I*
J	..	11	13	..	..	..	..	24	27	30	..	..	37	30	35	39	..	53	45	34	42	49	..	..	81	57	..	80	*J*
K	..	13	18	..	..	..	..	29	30	34	..	..	46	42	46	49	..	66	58	42	47	50	..	..	86	64	..	80	*K*
L	13	17	20	..	..	21	20	24	33	33	..	..	51	39	37	38	..	58	43	52	55	57	..	..	87	73	..	70	*L*
M	..	..	..	..	..	13	..	..	..	..	..	..	41	..	..	..	..	55	..	..	..	..	..	..	47[c]	..	..	80	*M*
M1	15	20	24	..	..	27	32	33	35	35	..	..	53	48	44	47	..	69	60	39	43	45	..	..	62	58	..	85	*M1*
M2	10	13	15	18	21	8	25	28	15	14	14	15	19	16	27	28[e]	29	30	33	48	31	32	33	35	37	51	..	80	*M2*
N	17	19	22	..	..	25	28	41	42	44	..	55	53	54	56	58	..	72	67	46	49	49	35	28	61	..	..	80	*N*
N1	15	11	16	20	23	10	..	15	15	15	17	22	25	..	41	35	32	33	36	61	..	35	35	34	35	28	61	..	*N1*
O	14	17	20	..	..	24	25	34	36	38	..	22	47	44	50	53	58	..	..	77	60	48	51	53	..	39	66	61	75	*O*
P	6	9	13	..	..	14	..	16	17	19	20	22	33	..	30	31	33	35	37	57	..	33	35	37	38	58	..	85	*P*
Q	12	16	19	21	17	17	..	..	30	26	23	24	49	..	41	39	37	36	35	70	..	45	43	41	39	36	..	75	*Q*
R	9	13	16	19	21	16	..	..	17	18	20	21	22	26	..	31	30	29	29	31	39	..	33	32	33	38	39	80	*R*
R1	..	..	..	..	..	13	..	..	..	..	..	..	..	32	..	..	..	..	..	..	49	..	..	..	..	..	43[c]	85	*R1*
S	11	12	13	15	20	16	..	..	16	16	16	17	20	31	..	39	40	41	42	44	62	..	39	41	43	45	48	63	..	*S*
T	..	..	..	..	..	23	..	..	..	..	..	..	..	72	..	..	..	..	..	..	88	..	..	..	..	..	..	86[c]	..	*T*
Average 13	15	18	19	22	20	26	26	27	29	25	27	43	43	38	39	39	41	38	39	59	54	39	41	42	40	42	61	56	..	Average

[a] The idling temperature recorded was that observed after the run at 40 m.p.h.
[b] The hill climb was at the maximum speed practicable on the hill whose profile is shown in Fig. 2, approximately 30 to 40 m.p.h.
[c] Temperature taken in carbureter bowl.
[d] Temperatures read at outlet of filter.
[e] Gravity fuel feed.

hundred times as many cars on the road of certain makes as there are of others listed in the tables, and it is desirable from some standpoints to have values for the average car on the road. To obtain temperatures approximately those representative of the average car, use was made of the most recent tabulation of car sales by makes in terms of percentages of total car sales. It was assumed for the present purposes that these percentages were indicative of the numbers of cars of corresponding makes on the road. For each car listed in Table 1, the appropriate temperatures were multiplied by the corresponding percentage of total car-sales. These products were added together and were divided by the total percentage for the cars concerned. On this basis, a gasoline must have a Reid vapor-pressure of less than 9.5 lb. per sq. in. if vapor lock is to

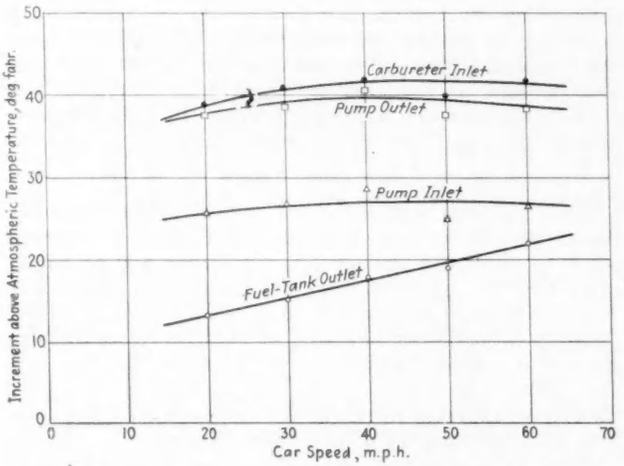


FIG. 5—AVERAGE EFFECT OF SPEED ON FUEL-LINE TEMPERATURES OF CARS TESTED

be avoided when driving at 40 m.p.h., in the average car on the road with an atmospheric temperature of 90 deg. fahr. During idling after such a run, the maximum vapor-pressure for protection is 6.5 lb. per sq. in. If 80 per cent of the cars on the road are to be protected from vapor-lock troubles, the corresponding vapor-pressures for 90-deg. atmospheric temperature at 40 m.p.h. and on idling after the 40-m.p.h. run are 7 lb per sq. in. and 5.5 lb. per sq. in. respectively. These vapor pressures are very low, and they reflect seriously on the design of automobile fuel-feed systems which will permit the attainment of such high fuel temperatures.

It should be emphasized that the values in Table 2 represent the increases in temperature of the gasoline in the fuel systems of the various cars above that of the atmosphere. By expressing the data in this form, it was felt that the values would be almost independent of the actual value of the atmospheric temperature, within reasonable limits. In extremely hot weather the temperature increases above atmospheric might be expected to be slightly lower than those recorded, while in cold weather, particularly below freezing, they would be somewhat higher. A difficult problem is presented from the standpoint of vapor lock in the early spring and late fall when a warm period occurs while winter gasolines are being marketed.

It should also be pointed out that most of the measurements were made on individual cars of each make. In only one case, cars *B* and *B1*, is a direct comparison of results possible on two cars of the same make and design, and the data are in good agreement. In the case of cars *M1* and *M2*, and cars *N* and *N1*, the last mentioned in each set differed from the first mentioned in that the fuel line from the rear tank was run outside of the frame channel rather than inside, thereby accounting for the observed decrease in temperature.

TABLE 3—AVERAGE AND EXTREME TEMPERATURE INCREMENTS AT 40 M.P.H., DEG. FAHR.

	Average	Maximum	Minimum
Fuel-Tank Outlet	18	29	8
Fuel-Pump or Vacuum Tank Inlet	29	49	10
Outlet	41	73	20
Carbureter Inlet	42	60	26

The effect of load is illustrated in Table 2 by the results obtained during hill climbing. A further illustration is given in Table 4 for six cars where increase in load was effected by one of the cooperating laboratories by towing a second car at 40 m.p.h. until the temperatures in the fuel-feed system reached constant values. In the hill-climbing tests, considerable increase in temperature was noted on the average, whereas the results shown in Table 4 indicate that there was little effect with the cars used, due to towing another car. Cars used in the towing tests incorporated changes which were intended to reduce the effect of heating. In the case of car *S*, runs were also made with two gear ratios, namely 3.9:1 and 4.6:1. At 40 m.p.h. the results in degrees fahrenheit above atmospheric temperature are as follows:

	3.9:1 Gear	4.6:1 Gear
Fuel-Tank Outlet	15	13
Pump Inlet	20	16
Pump Outlet	36	41
Carbureter Inlet	43	43

Again there is little difference in the values obtained.

Some conclusions regarding design factors can be drawn from the data in Table 2. A comparison of the worst car, *H*, and of the best car, *B*1, is interesting. Both have fuel-pump systems with the same make of fuel pump located in approximately the same position, namely on the right side toward the front. In the case of car *H*, the temperature increase at the fuel-pump outlet above the atmospheric temperature at 40 m.p.h. is 73 deg., whereas with car *B*1 it is only 22 deg. On idling after a 40-m.p.h. run, the values are 90 and 47 deg. respectively. Both engines have essentially the

TABLE 4—EFFECT OF LOAD ON FUEL-LINE TEMPERATURES AT 40 M.P.H., DEG. FAHR.

		Increment above Atmospheric Temperature				Average Atmospheric Temperature
Car	Test Conditions	Tank Outlet	Pump Inlet	Pump Outlet	Carbureter Inlet	
M2	No Load	15	14	29	33	80
M2	Towing	18	18	32	36	80
N1	No Load	16	15	32	34	80
N1	Towing	15	16	32	33	80
P	No Load	13	19	33	37	85
P	Towing	13	23	35	40	85
Q	No Load	19	23	37	41	75
Q	Towing	19	25	35	37	75
R	No Load	16	20	29	32	80
R	Towing	20	20	30	30	70
S	No Load	13	16	41	43	70
S	Towing	11	16	37	42	85

[c] Temperature taken in carbureter bowl.
[d] Gravity fuel feed. Temperatures read at outlet of filter.

TABLE 5—DESCRIPTION OF BUSES

Bus No.	Year	Fuel Feed	No. of Carbureters	Transmission	Service
1	1930	Pump[e]	2	Electric	City
2	1927	Vacuum	2	Electric	City
3	1930	Pump	2	Mechanical	Intercity
4	1930	Vacuum	2	Mechanical	Intercity
5	1928	Vacuum	1	Electric	Intercity
6	1927	Vacuum	1	Mechanical	Intercity
7	1930	Pump	1	Mechanical	Intercity
8	1930	Pump	1	Mechanical	Intercity

[e] An electrical pump is provided on this vehicle as reserve in case of vapor lock in the mechanical pump.

same rated horsepower and differ mainly in that the exhaust pipe in the case of car *H* is on the right side whereas in the case of car *B*1, it is on the left side. With both cars, the fuel line from the rear tank is on the right side. Much of the difference therefore lies in the proximity of the fuel-feed line to the exhaust pipe. Furthermore, the respective increases in temperature across the fuel pump were 24 deg. and 12 deg. fahr. The higher rise across the pump in the case of car *H* was due to the fact that it was more shielded from the air-stream than was the pump in car *B*1. With car *H* then, removal of the fuel line from the inside to the outside of the frame channel and thermally insulating it would do much to lower the temperature increase up to the pump. The lowering effected by this change in the case of cars *M*2 and *N*1 has already been pointed out. Also a redesign of the front end to prevent blocking the air-stream would reduce the temperature rise across the pump.

Some results were also obtained on car *R* by one of the cooperating laboratories in which provision was made for use of an exhaust outlet either at the front or the rear end of the engine. Using the front exhaust outlet, the temperature increase across the fuel pump at 40 m.p.h. was 10 deg., whereas with the rear exhaust outlet it was only 2 deg. However, the fuel temperature at the pump inlet was 8 deg. higher when using the rear exhaust outlet.

The same laboratory, employing car *S*, studied the effect of moving the fuel line from the inside to the outside of the frame channel and of placing a shield over the fuel-pump. The data obtained during a 40-m.p.h. run are given below where the temperatures are expressed as increases above that of the atmosphere, in degrees fahrenheit:

	Inside Line	Outside Line	Shield over Pump
Fuel-Tank Outlet	13	17	17
Pump Inlet	31	19	17
Pump Outlet	49	40	31
Carbureter Inlet	48	42	33

Moving the line outside the channel markedly lowered the temperature rise up to the pump, with a very great resultant decrease in the tendency to induce vapor lock, but it did not effect as large a change in the pump-outlet temperature. Use of the shield over the pump, in addition to the fuel-line change, was effective, however, in doing this, the temperature at the pump outlet being reduced 18 deg.

The temperatures in Table 2 are considerably higher than necessary, and it is felt that much can be done in the way of simple modifications which will go far to reduce fuel-line temperatures to reasonable values. If this is done, the automotive engineer has done his job in connection with the vapor-lock problem and the remainder is up to the petroleum refiner. Some simple points which should be kept in mind in designing fuel systems are as follows:

(1) The fuel feed line from the rear tank should preferably be on the opposite side of the car from the exhaust pipe
(2) If this is not feasible, the fuel feed line should be run outside of the frame channel and in addition should be thermally insulated from the exhaust pipe
(3) The fuel-pump should be well insulated thermally from the crankcase and shielded from the exhaust manifold
(4) The fuel-pump should be so located with respect to the engine supports and accessories as to get its full share of cooling from the air-stream

It is felt that the introduction of fuel-pumps has been more responsible for the widespread occurrence of vapor lock than has any increase in the average volatility of fuels during the last two years, and therefore it behooves the automotive engineer to do his part in keeping the fuel system as cool as possible. With some care and thought on the part of the engine designer, it is considered that the average increase in fuel temperature at the pump can be materially reduced.

Bus Fuel Lines

Each bus was run under its normal operating-conditions. A course was laid out with stops at marked points to simulate city-service conditions and at longer intervals for intercity service conditions. Runs up steep hills were also made with buses 1 and 2. Each run was of sufficient duration so that the temperatures reached a constant value at each point in the fuel system, after which the engine was allowed to idle with the transmission in neutral until the maximum temperature was obtained with each thermometer.

Data were obtained on eight buses, descriptions of which are given in Table 5. Three were of the gas-electric type and five of the gas-mechanical type. Five of them were 1930 models. Four were equipped with vacuum-tank systems and four with fuel-pump systems. One of the latter had a reserve electrical pump for use

TABLE 6—INCREMENTS ABOVE ATMOSPHERIC TEMPERATURE IN BUS FUEL SYSTEMS, DEG. FAHR.

No.	Operating Conditions	Fuel System[f]	Tank Outlet	Vacuum-Tank or Fuel-Pump Inlet	Vacuum-Tank or Fuel-Pump Outlet	Inlet Carbureter 1	Inlet Carbureter 2
1	City	*MP*	5	49	56	66	65
1	Idling	*MP*	5	78	83	84	76
1A	Hill	*MP*	5	49	51	59	60
1A	Idling	*MP*	5	88	95	90	81
1B	Hill	*EP*	8	..	37	51	52
1B	Idling	*EP*	8	..	63	83	83
2	City	*V*	—4	39	36	53	53
2	Idling	*V*	—4	52	42	73	..
2A	Hill	*V*	—4	25	34	73	..
2A	Idling	*V*	—4	59	45	83	..
3	Intercity	*MP*	0	19	27	37	38
3	Idling	*MP*	2	35	55	75	75
4	Intercity	*V*	7	18	22	19	22
4	Idling	*V*	8	41	36	34	30
5	Intercity	*V*	—4	34	36	35	..
5	Idling	*V*	—4	64	42	48	..
6	Intercity	*V*	13	36	43	45	..
6	Idling	*V*	13	69	59	69	..
7	Intercity	*MP*	3	23	32	39	..
7	Idling	*MP*	3	36	36	45	..
8	Intercity	*MP*	0	8	15	16	..
8	Idling	*MP*	0	14	24	27	..

[f] Symbols indicate as follows: *EP*, electrical pump; *MP*, mechanical pump; and *V*, vacuum tank.

(*Concluded on p.* 331)

Classifying Transmission and Rear-Axle Lubricants

By C. M. Larson[1]

Annual Meeting Paper

TRANSMISSION and rear-axle lubricants frequently have small quantities of soap or other material added to decrease the tendency of the lubricant to leak from the housings. Although these additions may increase the apparent viscosity of the oil, they may have little or no effect on the load-carrying properties at high temperatures or the tendency of the lubricant to channel or to make gear-shifting harder at low temperatures than with the straight oil.

On account of the many different conditions under which transmission and rear-axle lubricants are used and because of the many different methods of manufacture, no one detailed specification is applicable as an indication of the performance characteristics of a lubricant. Therefore, the author asserts, consumers must necessarily depend upon the individual oil companies to produce a quality lubricant, using for their guidance a viscosity, consistency and film-strength classification to be determined upon and subsequently published in the car manufacturers' instruction books.

TRANSMISSION and rear-axle lubricants are made from mineral oil with or without the addition of soaps. Since small quantities of soda, calcium, lead or aluminum-base soaps are added for the purpose of decreasing the tendency of the lubricant to leak from the housings, and because the demand for fluid-grease transmission and rear-axle lubricants has increased in the last three years, the classifying of these lubricants by the same system as mineral oils are classified is desirable.

The investigation reported in this paper covers the determination of Saybolt viscosities from −20 to +210 deg. fahr. and constitutes a classification in terms of viscosity, low temperature consistency, channel effect and drag resistance to shifting at low temperatures as well as non-leak and film strength at high temperatures.

Probably the most important phase of the subject at this time is the determination of viscosities of transmission and rear-axle lubricants at low temperature. A thorough knowledge of the low-temperature properties of such lubricants is essential in the development and classification of suitable products.

The Saybolt Furol instrument is of little value in determining viscosities at low temperature, and pour-test data are of no practical value in deciding whether a lubricant will function properly at low temperatures. The most accurate and satisfactory method of determining the viscosity of gear lubricants at any temperature from −20 to +100 deg. fahr. is by means of the pressure viscosimeter. Instruments of various designs have been employed by a large number, who invariably do not follow the same methods of operation. In basic principle, however, all instruments are very similar in that pressure is used to force the lubricant through an orifice.

Fig. 1 shows the tube (*a*) of the pressure-viscosimiter used by the Sinclair Refining Co. mounted in an insulated cabinet the temperature of which can be held

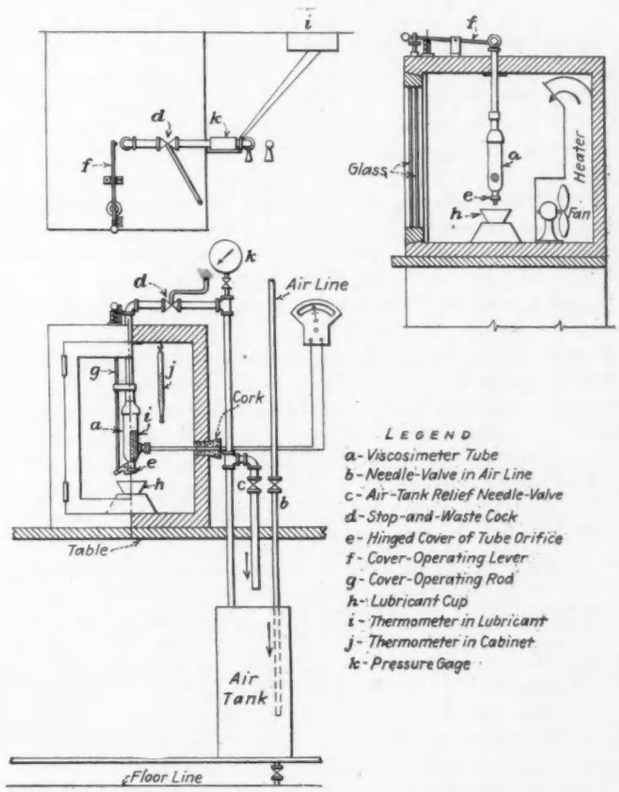


FIG. 1—SINCLAIR REFINING CO. PRESSURE VISCOSIMETER

A Cylindrical Nickeled-Steel Tube, *a*, for the Lubricant Sample Is Mounted in an Insulated Cabinet Which Can Be Maintained at a Constant Temperature within a Range from —25 to +225 Deg. Fahr. The Top Cap of the Tube Communicates with a Constant-Pressure Air-Tank below the Cabinet. Needle-Valves, *b* and *c*, Control the Pressure in the Tank, and a Stop-and-Waste Cock, *d*, Enables the Operator To Apply Pressure to or Release It from the Tube *a*. A Hinged Cover, *e*, at the Bottom of the Tube Is Operated by a Lever, *f*, and a Rod, *g*, To Release Lubricant into the Lubricant Cup, *h*

[1] M.S.A.E.—Supervising engineer, Sinclair Refining Co., New York City.

at temperatures ranging from −25 to 225 deg. fahr. The tube is a nickeled-steel cylinder 2 in. in diameter by 8 in. long, the top cap of which is connected to a ¾-in. pipe communicating with a constant-pressure air-tank. Accurate and convenient control of air pressure in the tank is accomplished by means of the two needle-valves, *b* and *c*, in the supply line and relief pipe respectively. The stop-and-waste valve *d* enables the operator to apply pressure to the lubricant in the tube or, at will, to cut off and instantaneously release the pressure within the tube. The hinged cover *e* is operated by a lever, *f*, and a rod, *g*, making unnecessary the opening of the cabinet door during the test.

About 100 cc. of the lubricant to be tested is brought to the temperature of the test. The tube is then filled about half full, or full when testing light lubricants at high temperatures, having the nickeled tube screwed in place and holding the cover tight against the Saybolt orifice. Next the tube is screwed into place, the rod attached to the cover and lever and the electric instrument connected to the nickel resistance plug, or a pour-test thermometer is inserted. The lubricant is brought to the desired temperature and, after a constant value has existed for 15 min., the determination is made.

[2] See Bureau of Mines Technical Paper 323B, 1927.

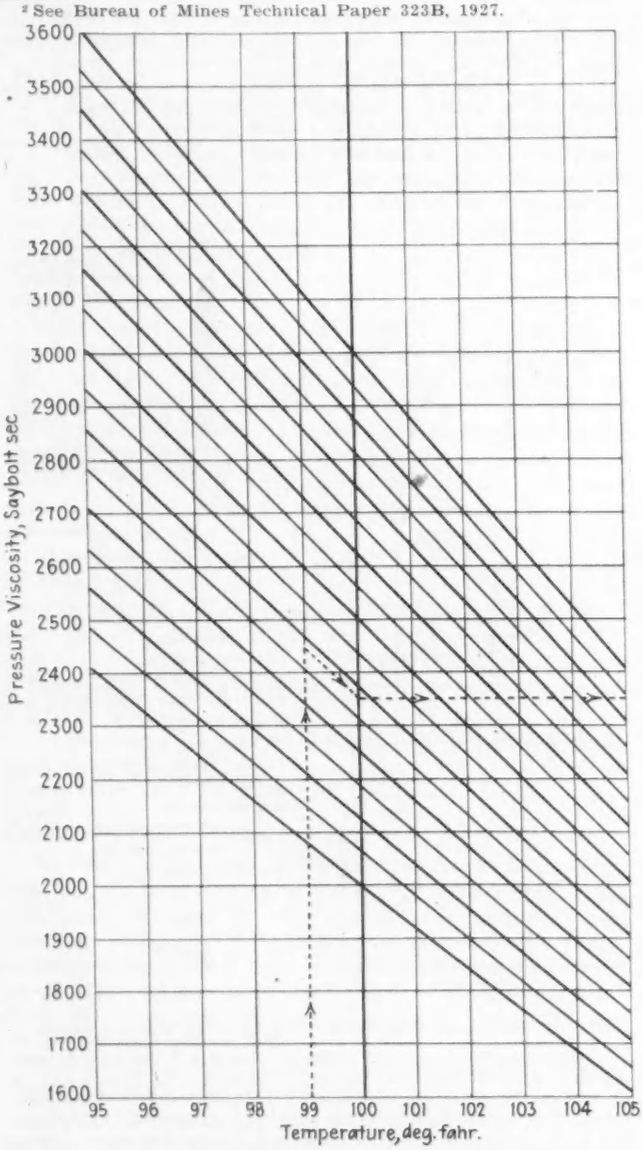


FIG. 2—PRESSURE-VISCOSIMETER TEMPERATURE-CORRECTION CHART FOR 100 DEG. FAHR.

This Chart Enables One To Quickly Make Temperature Corrections and Consistently Check Results to an Accuracy of 1 Per Cent

The stop-and-waste cock is now opened and air pressure in the tank and tube is gradually built up to the desired pressure, the pressure being adjusted by means of the two needle-valves. When the pressure remains constant for 1 min. and the thermometer still reads the desired test temperature, the orifice cover is quickly opened by latching the lever, simultaneously snapping a stop-watch. When the lubricant fills the cup about three-quarters full, the pressure in the tube is suddenly relieved by throwing the handle of the stop-and-waste cock and simultaneously stopping the watch, after which the lever is unlatched, closing the orifice cover.

The cup of expelled lubricant is removed and replaced with a clean cup, care being taken to avoid having the cabinet door open longer than is necessary. Pressure and temperature are checked and when both are again constant a check run is made. The lubricant is carefully weighed and the weight recorded to the closest 0.1 gram.

The formula generally employed is the one developed by Parsons and Taylor, two pioneers in the work. It is:

$$PV = 31{,}500\ te/W \qquad (1)$$

where

PV = Pressure viscosity, in Saybolt universal seconds
t = Time, in minutes
e = Load, in pounds per square inch
W = Weight, in grams

The viscosity-temperature chart, Fig. 2, enables one to make temperature corrections accurately and rapidly.

Numerous runs proved experimentally that the foregoing formula is correct and that the viscosity-temperature chart that has been developed is also correct throughout its entire range. With reasonable care and with special attention given to control of temperature and pressure, one can consistently check results to within 1 per cent. This is equal to or better than the accuracy obtainable with the Saybolt Universal instrument, which usually is not housed in an insulated cabinet and is therefore subject to temperature changes.

Pour-Point

The pour-point[2] of a petroleum oil is the lowest temperature at which this oil will pour or flow when it is chilled without disturbance under certain definite specified conditions. If a sample is known to have been subjected to some temperature higher than 115 deg. fahr. during the preceding 24 hr., or if the history of the sample in this respect is not known, the sample shall be held in the laboratory 24 hr. before testing, unless the results of three consecutive tests of the same sample under the same test check. For those particular oils this shall be called the upper (maximum) pour-point.

The pour-point of a gear lubricant is of little or no importance in determining whether the lubricant will feed satisfactorily to the ring gear and pinion or whether it will channel at zero temperature.

Viscosity may be defined as the resistance offered by

a fluid to the relative motion of its particles; that is, internal friction or cohesiveness. Viscidity, on the other hand, is the quality of being viscid, adhesive and ropy, or of a glutinous consistency. Viscidity expresses exactly the quality of the ideal gear lubricant, which should have a correct balance between its adhesiveness and its cohesiveness.

The pour test indicates only the consistency, or mobility at low temperatures, of a lubricant that is practically undisturbed.

The viscidometer, shown in Fig. 3, is a device for measuring the viscidity of an automotive-gear lubricant, indicating its suitability for use at low temperatures and whether it will channel[3]. The essential parts of the viscidometer are clearly shown in the drawings. These are a brass cylinder, *l*; a piston, *m*; an impelling weight, *n*; a spike-shaped plunger, *o*, having a 1/16 x ½-in. head and a ¼-in. shank; a test jar, *p*, with a 1.3-in. internal diameter; and a spring scale, *q*, for measuring the force required to push the spike into the lubricant. In the enlarged drawing of the spike jar at the right, note how the lubricant closes in more or less behind the spike head.

The method of test is briefly as follows: Two steel cylinders, jacketed like thermos bottles, are filled within 1 in. of the top with the lubricant to be tested and are tightly corked. A pour-test thermometer is inserted

[3] See Methods for Testing Automobile Gear Lubricants, American Petroleum Institute, Dec. 6, 1928.

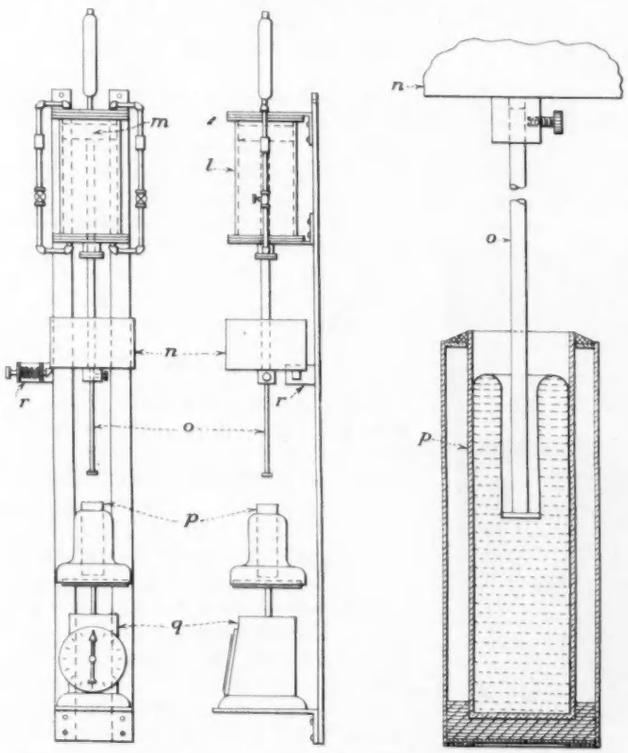


FIG. 3—KNOPF VISCIDOMETER FOR MAKING THE SPIKE TEST

The Essential Parts Are: *l*, Brass Cylinder; *m*, Piston; *n*, Impelling Weight; *o*, Spike Plunger; *p*, Test Jar; *q*, Spring Scale; *r*, Weight-Release Latch. An Enlarged Detail of the Spike and Jar Is Shown at the Right. Samples of Lubricants Are Placed in Jars and Cooled to a Uniform Temperature. A Jar Is Then Placed in a Holder on the Scale, Which Is Adjusted to Zero. A Spike Is Fastened in the Chuck of the Weight, Which Is Then Released. When the Head of the Spike Enters the Lubricant in the Jar, the Scale Registers Nearly the Correct Test Value

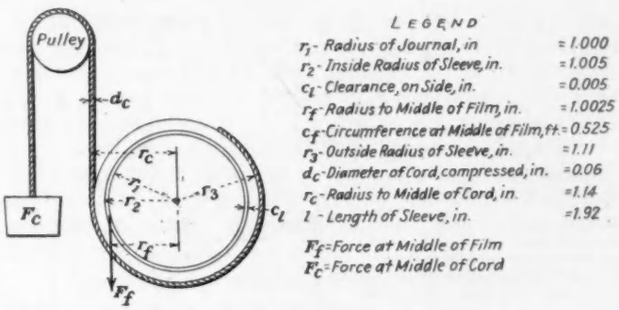

Pulley
d_c
r_c
r_1
r_2
r_3
c_l
F_c
r_f
F_f
LEGEND
r_1 - Radius of Journal, in = 1.000
r_2 - Inside Radius of Sleeve, in. = 1.005
c_l - Clearance, on Side, in. = 0.005
r_f - Radius to Middle of Film, in. = 1.0025
c_f - Circumference at Middle of Film, ft. = 0.525
r_3 - Outside Radius of Sleeve, in. = 1.11
d_c - Diameter of Cord, compressed, in. = 0.06
r_c - Radius to Middle of Cord, in. = 1.14
l - Length of Sleeve, in. = 1.92
F_f = Force at Middle of Film
F_c = Force at Middle of Cord

FIG. 4—DEVICE FOR MAKING SLEEVE TEST

A Brass Sleeve Revolves on a 1-In. Fixed Shaft to Which Is Fixed One End of a Cord That Is Wound around the Outer Casing of the Sleeve and Passes over a Pulley to a Weighing Device. The Shaft and Sleeve Are Coated with the Lubricant To Be Tested and then Chilled to the Required Temperature. The Weight, in Pounds, That Is Necessary To Revolve the Sleeve Is Recorded as the Measure of Resistance of the Lubricating Film between the Sleeve and the Shaft

in one of the samples. The two jars, together with other samples at the same temperature, are placed in a refrigerating medium and allowed to cool slowly until they all reach a uniform temperature, which may be any value above or below 0 deg. fahr.

The best method of cooling the samples is to place the jars in a cabinet the air of which is circulating and somewhat colder than the temperature of the test. When the blank thermometer reads a few degrees above the temperature of the test, the jars are placed in a current of air maintained exactly at zero. After the blank thermometer has been held at zero for 15 min., one can be reasonably certain that all jars are of a uniform temperature of 0 deg. fahr. Ice and salt, in proportions to give a temperature of −5 deg. fahr., may also be employed, but the temperature is more difficult to control.

The sample, at 0 deg. fahr., is placed in the holder, also at 0 deg. fahr., which is placed on the scale, and the scale is adjusted to read zero. A "spike," also at 0 deg. fahr., is quickly fastened in the chuck and the weight *n* is released at the latch *r*. Almost immediately after the head has entered the lubricant, the scale indicates nearly the correct value. Weights equal to or greater than this value are added to the driving weight so as to compensate for loss due to the upward resistance of the lubricant. A buzzer sounds at points ½ in. above and below the middle of the sample, at which points the scale is read. The average of the two readings is taken as the viscidity of the lubricant in ounces. This is a measure of the mobility of the lubricant at 0 deg. fahr. as well as its drag on gears.

Exactly 1 min. after the head enters the lubricant, the spike is pulled out of the jar. The quantity of lubricant adhering to the spike and the distance it "strings" out are indicative of the non-channeling and feeding quality of the lubricant. This quality is noted as grade *A*, *B*, *C* or *D*, meaning excellent, good, fair and poor. Grade *D* represents a condition in which virtually no lubricant flows behind the head, denoting possible channeling.

The Sleeve Test

The sleeve test, shown in Fig. 4, is made by means of a 1-in. fixed steel shaft about which revolves a brass sleeve. A cord wound around the outer casing of the sleeve and having the end fixed to the sleeve is carried

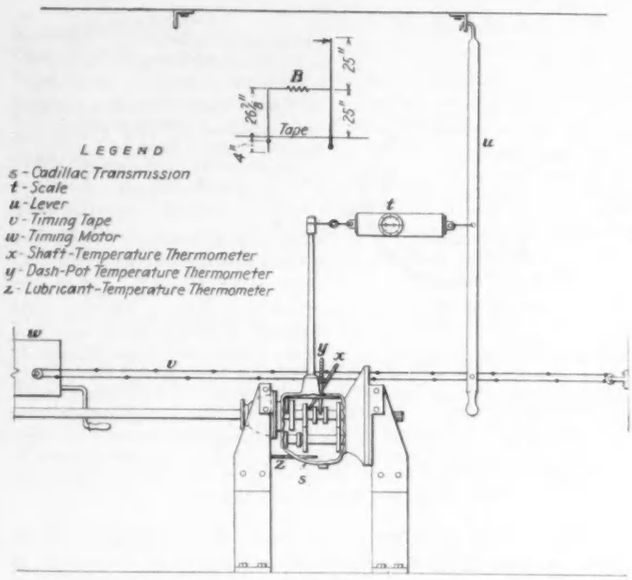


FIG. 5—DEVICE FOR MAKING TRANSMISSION GEARSHIFT TEST

The Transmission, *s*, Is Set up in a Low-Temperature Room and Directly Connected to a Dynamometer Outside of the Room. A Spring Scale, *t*, Indicates the Resistance to Shifting of the Gears as Applied by a Lever, *u*. A Timing Tape, *v*, Driven by a Phonograph Motor, *w*, Assures a Uniform Rate of Shifting. Thermometers, *x*, *y* and *z*, Show the Temperature of the Lubricant in the Transmission

over a pulley to a weighing device. The shaft and sleeve are coated with the lubricant and the assembly is chilled to the required temperature before each run, the weight in pounds necessary to revolve the sleeve at a definite rate being recorded.

By the use of this apparatus it is possible to measure the resistance set up by the lubricating film between the sleeve and the shaft.

The general formula for all types of resistance may be expressed as follows,

$$R = F/Q = Ft/s \qquad (2)$$

Where

F = Impelling force
Q = Rate of displacement
R = Resistance
s = Distance
t = Time

The sleeve-test resistance equals the shearing force at the middle of the film divided by the rate of displacement.

$$R_s = F_f t/s = F_f t/s_c = F_c\,(r_c/r_f)\ (t/c_f)$$
$$= F_c\ (1.14/1.0025)\ (t/0.525) = 2.16\ F_c t$$

Where

c_f = Circumference at middle of film, in inches
F_c = Force at middle of cord, in pounds
F_f = Force at middle of film, in pounds
r_c = Radius of sleeve to middle of cord, in inches
r_f = Radius of sleeve to middle of film, in inches
R_s = Sleeve-test resistance, in pounds
s = Displacement, in feet
s_c = Circumference of sleeve, in feet
t = Time of test, in seconds

Comparisons are made at the standard rate of 30 sec. for one revolution of the sleeve and for a sleeve 1 in. wide. The final formula then becomes

$$R_s = 2.16\ F_c \times 30/1.92 = 33.7\ F_c \qquad (3)$$

for a sleeve 1 in. wide and a rate of 30 sec. per revolution.

Allowing about 2 per cent for friction of the pulley, the 0.7 above may be discarded. Then

$R_s = 33\ F_c$ (lb-sec. ÷ ft. of displacement).

A grooved pulley having an effective radius five times that of the standard sleeve is used for very low temperatures, the bearing being a sleeve of standard dimensions. When using this outfit, all values of F_c are multiplied by 5 and recorded as if the load were applied at radius r_c.

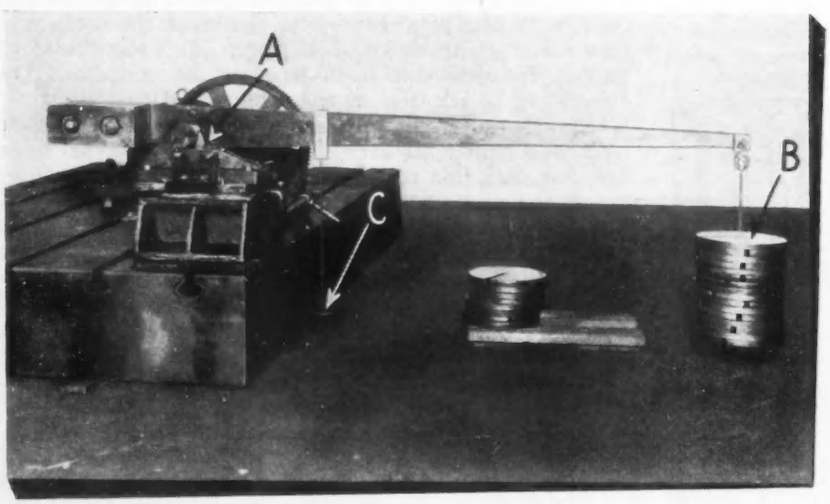


FIG. 6—MACHINE FOR TESTING LUBRICATING-FILM STRENGTH

A Steel Test-Pin, *A*, Is Turned at a Constant Speed within Three Steel Bushings Running in an Oil Bath. The Bushings Are Supported by a Housing That Keeps Them in Absolute Alignment and Serves as a Reservoir for the Lubricant Being Tested. A Substantial Lever Is Rotatably Mounted on the Housing and Has a Counterweight on the Short End and Two Poises, *B* and *C*, on the Long Arm. These Poises Are Located To Give Ratios of 40:1 and 10:1. Discs Weighing 25 Lb. Each Are Applied to the Poises To Increase the Load on the Oil Film on the Pin. The Pin Is Driven by a Constant-Speed Motor and a Reduction Gear at 100 R.P.M. Variation in the Current Required Indicates the Performance. When the Film Breaks, the Shaft Seizes and the Weights on *B* and *C* Give the Film Strength in Pounds per Square Inch

Transmission-Shift Test

The purpose of this test is to determine the relative shifting resistances offered by typical gear lubricants in a Cadillac synchro-mesh transmission, at temperatures between −20 and +40 deg. fahr.

The apparatus used, as shown in Fig. 5, is comprised of a transmission, *s*, set up in a low-temperature room; a dynamometer, directly connected outside the room; a spring scale, *t*, for reading the shifting force; a lever, *u*, for applying force; timing tape, *v*, to assure a uniform rate of shifting in all tests; a phonograph motor, *w*, to drive the tape; and thermometers, *x*, *y*, *z*, and stopwatches.

The driveshaft is rotated at 600 r.p.m. for about 15 min. before taking a set of readings at any given temperature, so that all rubbing surfaces will be thoroughly coated.

Thermometers x and y, inserted through holes in the cover, indicate the temperature of the shaft and the dash-pot respectively. The entire outfit is brought to about −20 deg. fahr. by means of a cold blast of air directed against the transmission case. Before taking any set of readings, all thermometers, including the room thermometer, must read the same and be constant for ½ hr.

When the desired temperature has been reached, thermometers x and y are removed. Proper meshing of the gears is effected by turning the clutch-shaft with a lever. One engagement is made, without noting the scale reading, preceding three determinations in each shift position. Readings are taken from neutral to each position in the following order:

Neutral to reverse, neutral to second, neutral to first, neutral to third or high.

The timing tape travels at the rate of 2 in. per sec. and the shift-lever knob at 1 in. per sec. This rate is somewhat slower than one employs in actual service, but it is very satisfactory for test purposes. The gear moves at the rate of 1/6.7 x 1/12, or 1/80.5, or 0.0124 ft. per sec., which is exactly the speed of the spike in the viscidometer spike test. As the scale readings are non-uniform during each stroke, maximum readings only are recorded. The unit used in this test is based on the general formula

Resistance = impelling force / rubbing speed.

The transmission-shift resistance is then

$$R_t = F_g/V_g = F_h \times 6.7/0.0124$$
$$= F_h \times 6.7/0.0124 = 540\,F_h \text{ (pounds} \times \text{sec. per ft.)}$$

where F_g = Force at gears, in pounds
F_h = Force at hook, in pounds
V_g = Rubbing speed of gears, in feet per second.

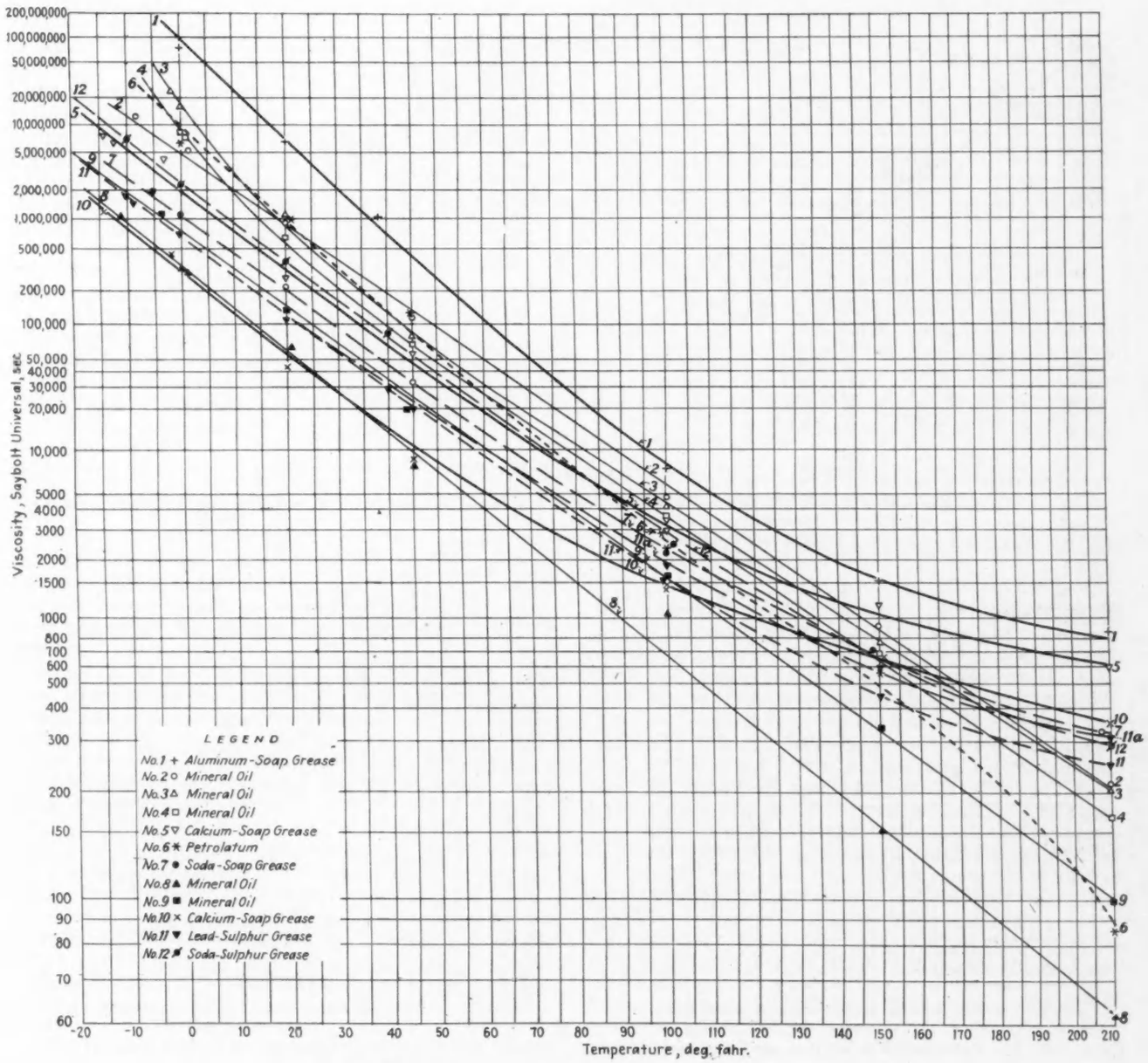
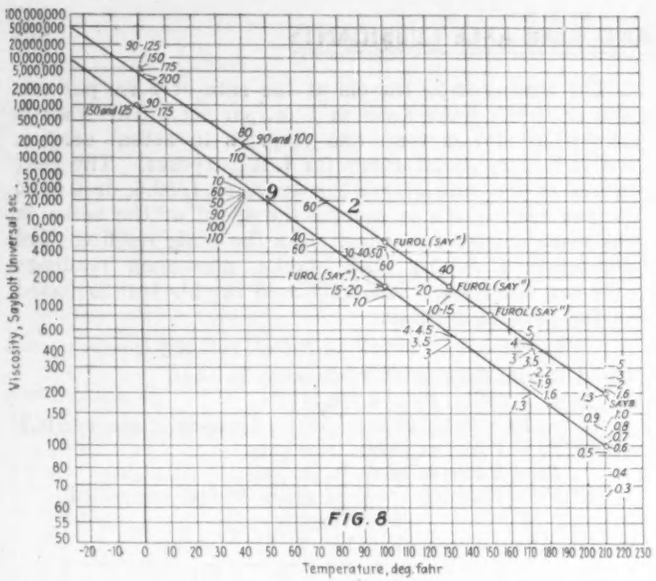
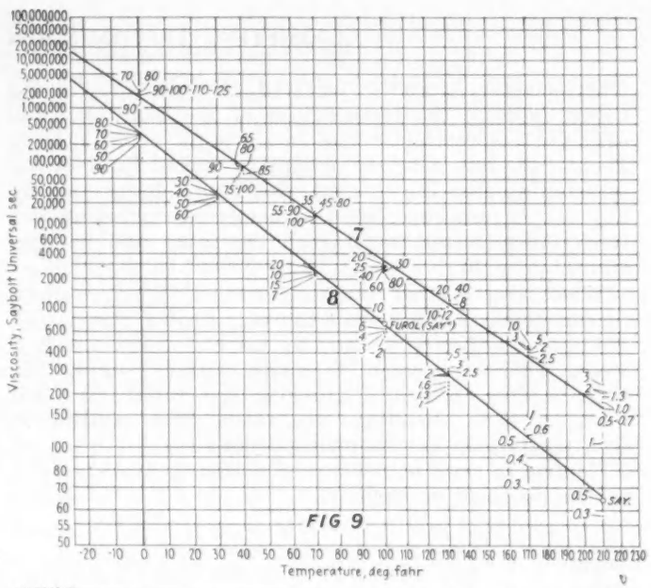
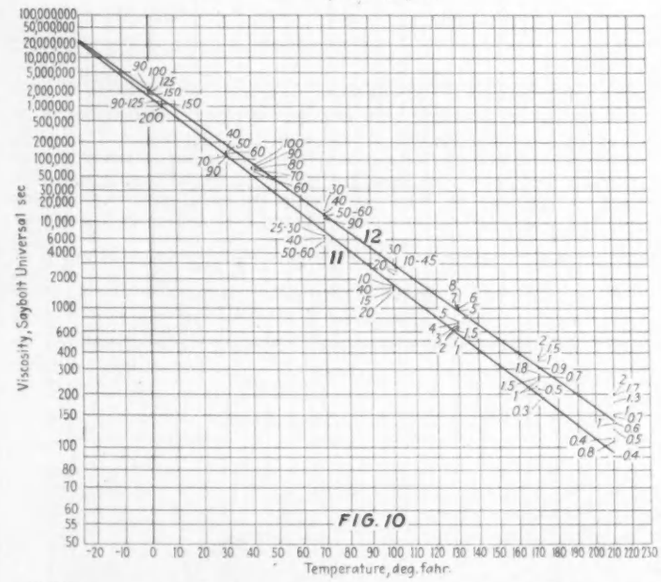
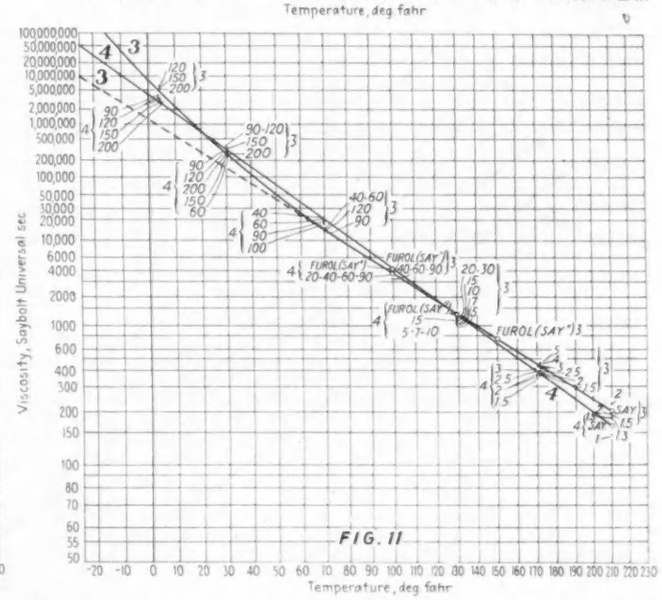


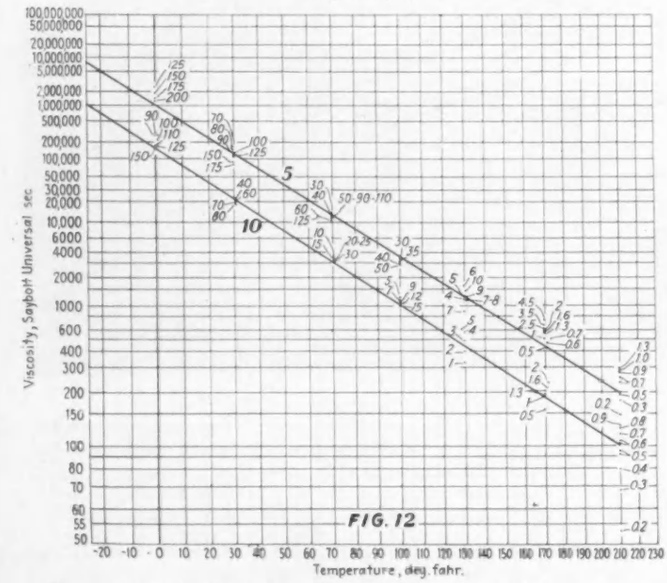
FIG. 7—PRESSURE VISCOSITIES OF TYPICAL GEAR-LUBRICANTS

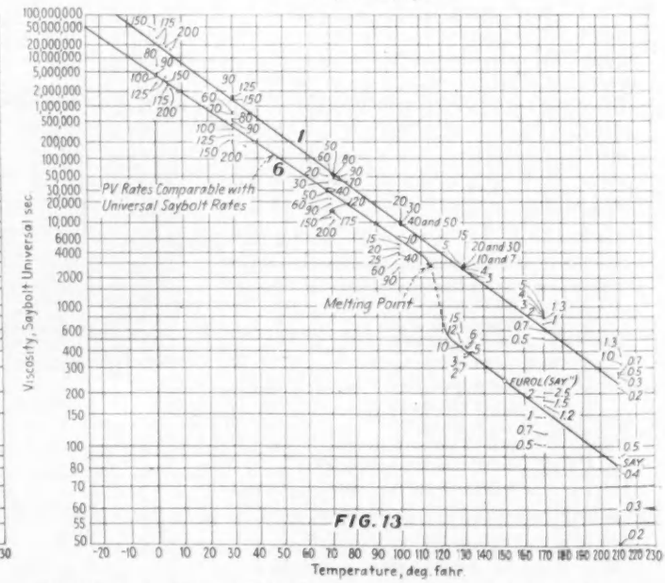












FIGS. 8 TO 13—PRESSURE VISCOSITIES OF LUBRICANTS, WITH SAYBOLT AND FUROL VISCOSIMETER DETERMINATIONS PLOTTED FOR THE STRAIGHT-LINE VISCOSITY CURVES

These Curves Show the Effect That Different Pressures at the Same Temperatures Have on the Entire Series of Lubricants

This is the unit used in the sleeve test and pressure viscosimetry.

Determinations are made at approximately −20, −10, 0, 10, 20 and 30 deg. fahr. The scale readings are multiplied by 540 to express the shifting forces in R_t units, which values are then plotted. Care must be exercised in cleaning the case thoroughly with gasoline and alcohol before filling with the test sample.

Lubricating-Film Strength

The ability of an oil to resist the squeezing action of extremely high unit-pressures without complete rupture of the film is determined by the film strength of the oil, which is independent of all other physical properties except viscosity. Slightly greater unit-pressures may be carried as the viscosity increases but not in the same ratio. Certain high-viscosity oils sustain comparatively high unit-pressures but attain such a high temperature under this severe treatment that their characteristics are changed, resulting in eventual failure of the lubricant and endangering the contact surfaces of the metal so that scuffing occurs.

Certain compounds added to the mineral oil enhance the ability of the oil to resist rupture at high unit-pressures.

Perhaps the most important consideration is the determination of the point of complete failure at comparatively low speed. A knowledge of this failure point is necessary when recommending lubricants for gears such as the hypoid, which utilizes extremely high tooth-pressures in combination with a characteristic sliding action at the line of contact, and for worm gears, which develop high tooth-pressures in combination with sliding-contact surfaces.

Many investigators have attacked the problem, each from the viewpoint he considered most effective for his needs, but it is not easy to duplicate results. In conjunction with a large laboratory devoting its entire time to research, the Sinclair Refining Co. has built a machine that can be depended upon to duplicate results within very narrow tolerances.

The machine[4], shown in Fig. 6, for testing the lubricating-film strength consists essentially of a steel pin, *A*, which is turned at a constant speed by suitable means within three steel bushings running in a bath of lubricant. A housing that acts as a support for the bushings and is substantial enough to keep them rigidly in absolute alignment provides ample space for the lubricant being tested. This housing has projections that provide a fulcrum pin upon which a substantial lever is rotatively mounted. A counterweight is mounted on this lever, and two poises are located so that ratios of 40:1 and 10:1 can be obtained.

The pin *A* is exactly 1 in. in diameter and 3 in. long plus or minus 0.0005 in., and has a hexagonal head ½ in. long to provide means for turning. The bushings completely envelop the pin and have an internal diameter of 1 in. plus 0.007 in. to allow ample space for viscous lubricants. The two end-bushings are rigidly held in a suitable retainer and the center bushing is held against turning in a suitable link but is free to move vertically with the link that transmits the load from the lever to the pin.

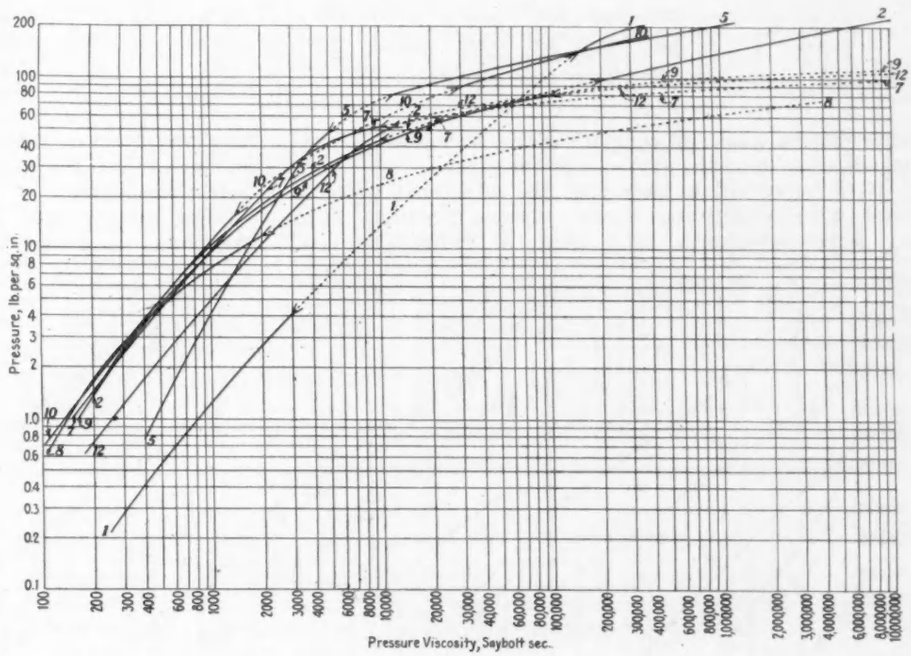


FIG. 14—APPROXIMATE PRESSURES NECESSARY FOR OBTAINING STRAIGHT-LINE VISCOSITY CURVES FOR VARIOUS GEAR LUBRICANTS

In the Range from 14,000 to 40,000-Sec. Pressure Viscosity, the Variation of Pressures Has the Least Effect on Diverting the Curves from the True Straight-Line Plot of the Viscosity-Temperature Curves

Discs weighing 25 lb. each are provided and, when these are applied upon the 40:1 poise, *B*, a load of 1000 lb. is imposed upon the projected area of the pin within the center bushing. This area is exactly 1 sq. in. When the discs are applied upon the 10:1 poise, *C*, a load of 250 lb. is imposed upon the same area.

The pin is driven through a flexible coupling-link located within the oil well to facilitate removal of the pins. By means of a constant-speed motor and a reduction gear, the pin is turned at exactly 100 r.p.m. The motor must be of ample capacity so that no variation in speed occurs even though chattering starts, because slight variations from the predetermined rate of speed result in actual seizure and damage to the machine.

A voltmeter and an ammeter are provided, and the variation in the current supplied indicates the performance.

One weight is added every 10 sec. until the oil film ruptures, which is indicated by the ammeter reading. The load is then removed with the motor still operating and the pin turning, so that a true estimate of perform-

[4] See The Significant Properties of Automotive Lubricants, presented before the American Society for Testing Materials, Detroit, March 10, 1930.

TABLE 1—TRANSMISSION AND REAR-AXLE LUBRICANTS

No.	Lubricant Type	Viscosity at 210 Deg. Fahr.	Pour-Point	Soap, Per Cent[a]	Water, Per Cent[a]	Nature of Soap	Oil, Per Cent	Separated Oil Viscosity at 210 Deg. Fahr.
1	Aluminum-Soap Grease	532	36	9.02	0.25	Aluminum Stearate	90.59	209
2	Mineral Oil	195	—2	Nil	Nil	.....	100 A-200	195
3	Mineral Oil	209	35	Nil	Nil	.....	100 Penn Cyl. Stk.	209
4	Mineral Oil	167	—5	Nil	Nil	.....	100	167
5	Calcium-Soap Grease	370	102	11.27	1.10	Calcium	86.55	80
6	Petrolatum	86	115	Nil	Nil	.....	100 Petrolatum	86
7	Soda-Soap Grease	343	—5	4.8	Nil	Soda	95.2	99.5
8	Mineral Oil	64	—15	Nil	Nil	.....	100	64
9	Mineral Oil	100	5	Nil	Nil	.....	100	100
10	Calcium-Soap Grease	109	110	5.29	1	Calcium	92.61	68.5
11	Lead-Sulphur Grease	127	10	12.9	Nil	Lead Oleate	86.44	90
12	Soda-Sulphur Grease	165	15	4.8	Nil	Soda	92.0	92

[a]A.S.T.M. Grease Method D-128-27, 1930 report D-2, p. 39.

ance can be made by comparing the scratches, if any, which show upon the surfaces of the pins.

It is important to note that the 40:1-ratio poise is used when examining heavy, viscous products such as gear lubricants, and that a combination of the 40:1 and the 10:1 poises is used when examining oils of comparatively low viscosity.

The results are plotted as applied pressure against meter reading in amperes on cross-section paper.

This machine has the advantage of showing quickly the actual load in pounds per square inch that a lubricant may be expected to sustain without rupture with the minimum quantity of oil.

The lubricants selected for this investigation are mostly nationally distributed products. They represent the diversified types of transmission and rear-axle oils and greases and are a true cross-section of this field of lubricants. They are listed in Table 1, with data on their viscosity, pour-point and the percentages of soap and water in their composition.

When the pressure viscosities were plotted for the lubricants, as shown in Fig. 7, the points for the

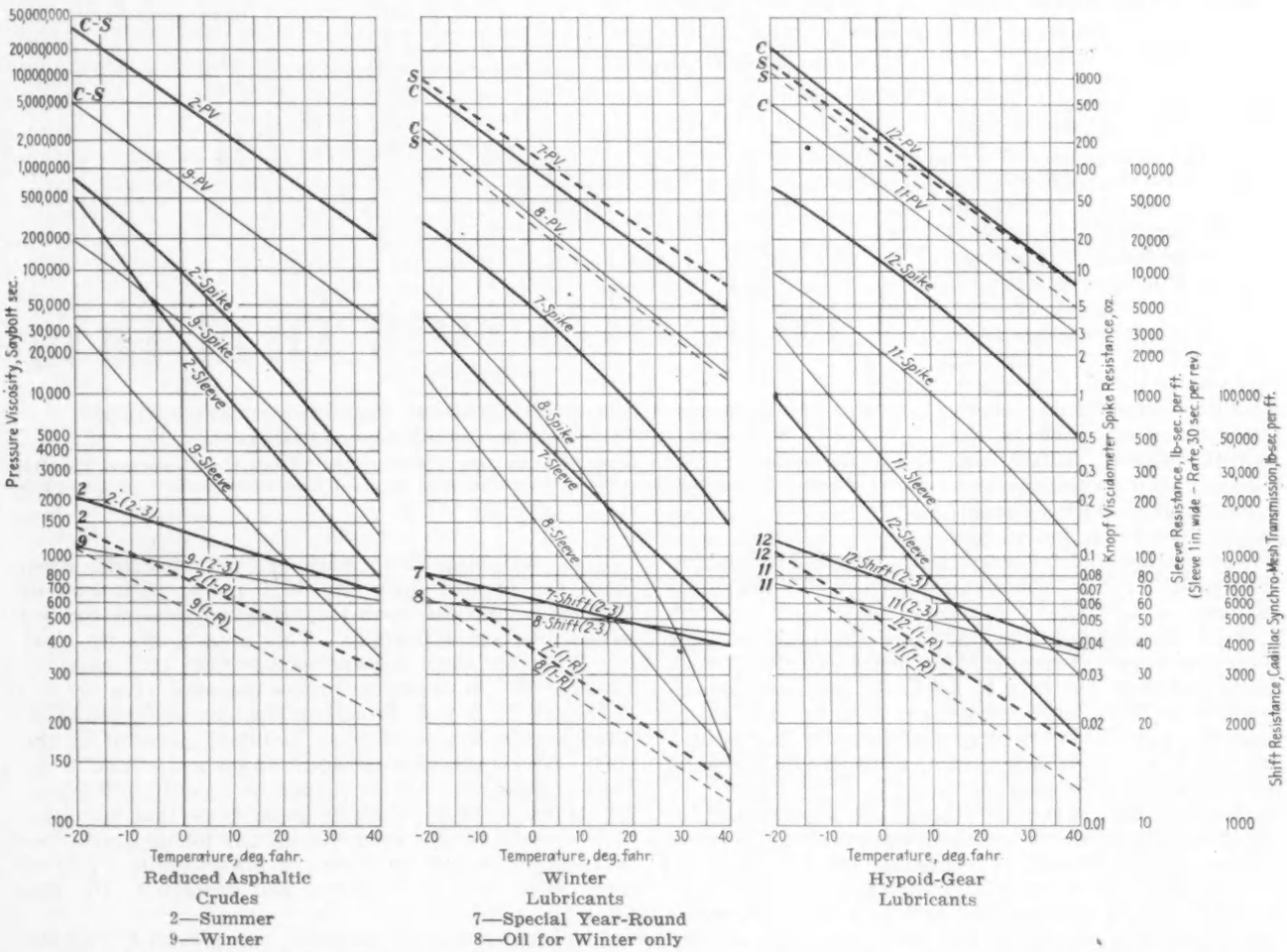

Pressure Viscosity, Saybolt sec.
Temperature, deg. fahr.
Reduced Asphaltic Crudes
2—Summer
9—Winter
Winter Lubricants
7—Special Year-Round
8—Oil for Winter only
Hypoid-Gear Lubricants
Knoop Viscidometer Spike Resistance, oz.
Sleeve Resistance, lb-sec. per ft. (Sleeve 1 in wide – Rate, 30 sec. per rev)
Shift Resistance, Cadillac Synchro-Mesh Transmission, lb-sec. per ft.

FIG. 15—SUMMARY CHARTS OF PRESSURE VISCOSITY AND SPIKE TESTS AND THE SLEEVE AND GEARSHIFT RESISTANCE OF SIX LUBRICANTS

C=Constant Pressure of 90 Lb. *S*=Straight-Line Pressures. Solid Heavy and Light Lines Indicate, for Two Lubricants, (*a*) the Pressure Viscosity, (*b*) the Viscidity by the Spike Test, (*c*) the Oil-Film Shear Resistance by the Sleeve Test and (*d*) the Average Resistance to Gearshifting from Second to Third Speed. Broken Heavy and Broken Light Lines Indicate for the Same Two Lubricants the Average Resistance to Shifting from First to Reverse

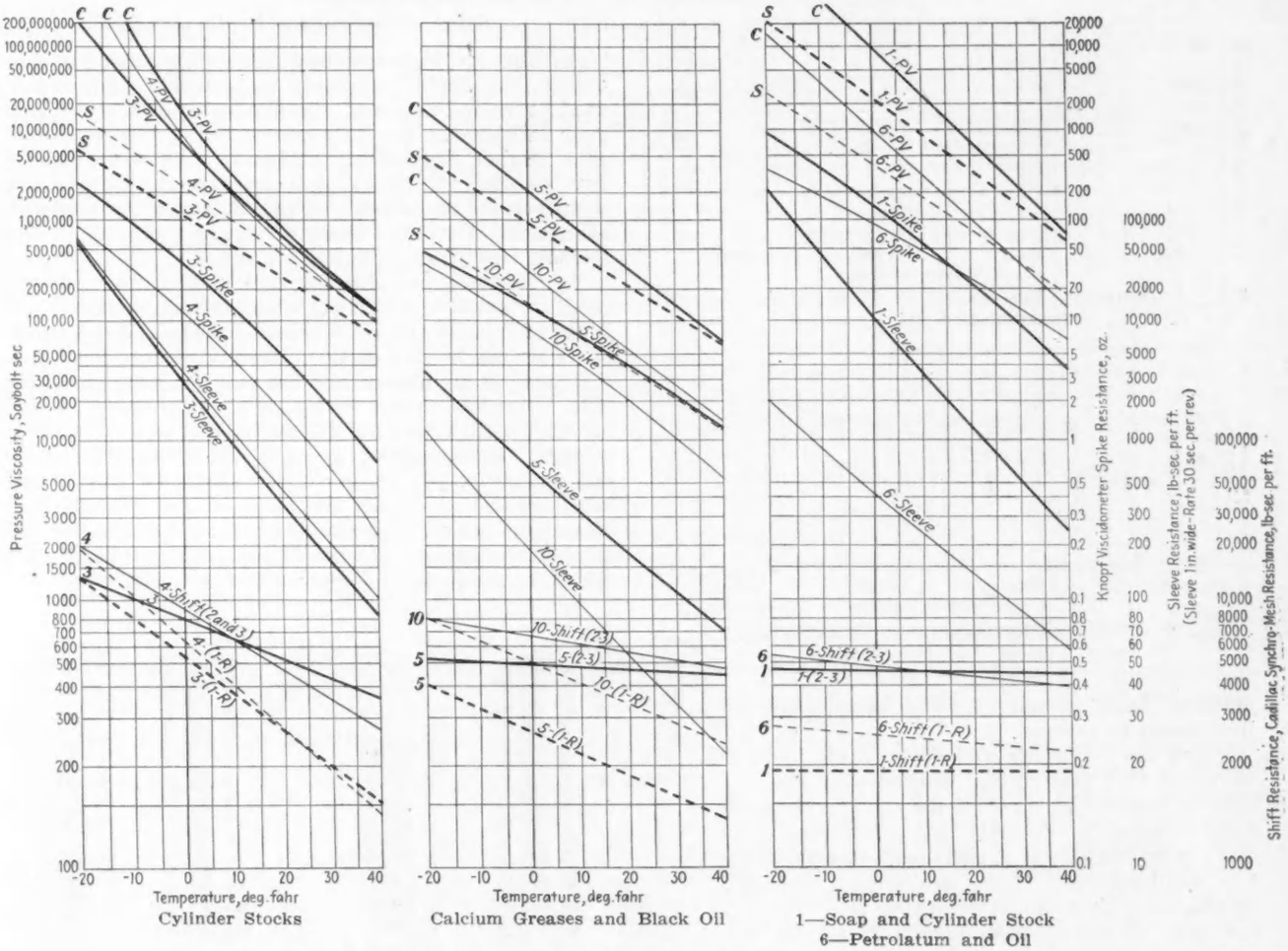

Pressure Viscosity, Saybolt sec
Temperature, deg. fahr
Cylinder Stocks
Calcium Greases and Black Oil
1—Soap and Cylinder Stock
6—Petrolatum and Oil
Knopf Viscidometer Spike Resistance, oz.
Sleeve Resistance, lb-sec per ft. (Sleeve 1 in. wide - Rate 30 sec per rev)
Shift Resistance, Cadillac Synchro-Mesh Resistance, lb-sec per ft.

FIG. 16—SUMMARY CHARTS, SIMILAR TO FIG. 15, FOR SIX OTHER LUBRICANTS

straight petroleum oils without petrolatum fell on a straight line, whereas those for greases and special lubricants, although almost straight at low temperatures, seemed to fall in a curve rising above the straight line at high temperatures. This condition was thought at first to result from the soap content of the greases, but, when this phase was investigated further, the fact developed that the rate of flow exceeded the designed speed of the Saybolt viscosimeter with the kinetic energy added to the true viscosity and that this was the cause for the viscosity curve bending upward at the higher temperatures.

Figs. 8 to 13 inclusive show the effect that different pressures at the same temperatures have on the entire series. In addition, the Saybolt and Furol viscosimeter determinations are plotted on the same charts for the straight petroleum oils such as lubricants Nos. 2, 3, 4, 8 and 9. Fig. 14 shows the approximate pressures for obtaining straight lines for various gear lubricants. Note that between the range of 14,000 and 40,000-sec. viscosity, the variation of pressures used has the least effect on diverting the line from the true straight-line plot of the viscosity-temperature curve.

The summary charts, Fig. 15 and 16, give a complete plot of the 12 transmission and rear-axle lubricants, arbitrarily grouped in six sets. This was done for convenience and simplicity rather than for classification purposes. Note that the pressure-viscosity curve, marked *PV*, is given for each product, using the same numbers as are given for the lubricants in Table 1. The spike, or viscidity, curve is next shown, plotting ounces of resistance against temperatures from −20 to +40 deg. fahr. The sleeve-test resistances in pound-seconds per foot are also shown over the same temperature range. Finally, the plotting of the two shifting-resistances of the Cadillac synchro-mesh transmission is given in pound-seconds per foot for the resistance to

TABLE 2—RELATIVE RATINGS OF TRANSMISSION AND REAR-AXLE LUBRICANTS

Lubricant No.	Order of Viscosity: Pressure Viscosimeter 0 Deg. Fahr.	Pressure Viscosimeter 70 Deg. Fahr.	Viscosity of Separated Oil at 210 Deg. Fahr.	Saybolt Viscosity at 210 Deg. Fahr.	Combined Order of Shift at 0 Deg. Fahr.	Spike Test at 0 Deg. Fahr.	Sleeve Test at 0 Deg. Fahr.	Remarks
10	1	2	2	5	6	5	3	
8	2	1	1	1	3	1	2	
9	3	3	3	4	2	3	5	
5	4	4	4	10	9	2	8	
7	5	7	7	7	4	9	7	
11	6	5	5	3	5	4	4	
12	7	6	6	6	7	8	1	
4	8	9	9	8	10	7	11	
6	9	11	4	2	1	11	6	Channels at 22 deg. fahr.
2	11	11	10	8	12	6	9	
3	11	8	11	11	8	10	10	Channels at 5 deg. fahr.
1	12	12	12	12	12	12	12	Channels at 18 deg. fahr.

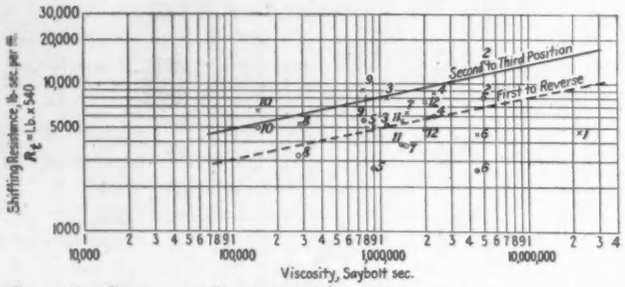


FIG. 17—SHIFTING RESISTANCE OF LUBRICANTS AT A TEMPERATURE OF 0 DEG. FAHR.

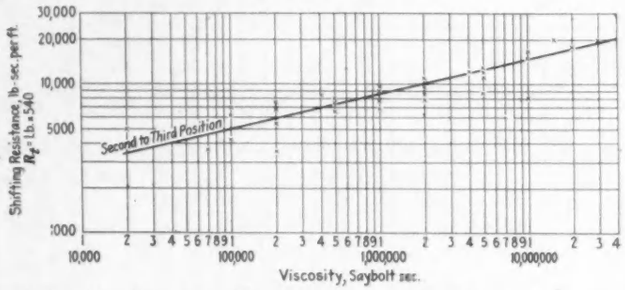


FIG. 18—SHIFTING RESISTANCE AT TEMPERATURES FROM −20 TO +40 DEG. FAHR.

shifting from second to third speed and from first speed to reverse.

From the foregoing and from Table 2, it will be noted that classifying transmission and rear-axle lubricants, whether of the oil or fluid-grease type, in terms of viscosity and consistency (spike test) is an indication of their performance only at low temperatures. There are factors of quality or character that can be evaluated only by practical tests. However, from results of former work done on a Studebaker transmission and rear-axle set-up as well as numerous field tests, it was proved that the moment the viscosity of a lubricant reaches a point higher than 1,500,000 Saybolt sec., the power drag and resistance to shifting become too great. Referring to Fig 17, it will be noted that, when the resistance set up in shifting the Cadillac transmission at 0 deg. fahr. is plotted against the viscosities of the lubricants in Saybolt seconds at 0 deg. fahr., there is a definite relationship; that is, the resistance to shifting increases proportionately to the increased viscosity of the lubricant.

Fig. 18 is a plot of shifting resistances versus viscosities taken over the temperature range of −20 to +40 deg. fahr., and shows a similar relationship to that in Fig. 17. Recent reports made by both H. C. Mougey and D. P. Barnard to the Lubricants Division of the Society's Standards Committee also show conclusively that the shifting effort in a transmission is proportional to the viscosity of the lubricant, independently of the body resulting from the soap content.

There is one exception to this; namely, the lubricant which channels and consequently is not picked up into the mesh. This is clearly the case with lubricants Nos. 1 and 6. These would be classified as poor winter gear-lubricants and would be eliminated if the maximum viscidity rating (spike, in ounces) were established to assure against channeling.

High-Temperature Performance

As far as high-temperature performance is concerned, the Saybolt viscosity at 210 deg. fahr. can be used as an indication of the non-leak properties of the gear lubricant. For this reason fluid greases, which show higher Saybolt viscosities at high temperatures, have gained in favor. Yet their true viscosities at low temperature, as shown by the pressure viscosimeter, are much lower than those of straight oils of similar Saybolt viscosities at 210 deg. fahr.

To duplicate performance under conditions encountered in rear-axle operation, where intense pressures are found, film-strength tests should be run and the lubricants graded as in Fig. 20. Here lubricants Nos. 2, 7, 9, 11 and 12 are shown, and the pins for each run made with them are shown in Fig. 19. Lubricants 11 and 12 withstood a load of 26,500 lb. per sq. in. without seizure. Lubricants 9, 7 and 2 failed at 7800, 10,750 and 11,250 lb. per sq. in respectively. To two lots of lubricant No. 7, 4 per cent and 10 per cent of lead oleate was added. These lubricants are shown for the sake of comparison as Nos. 13 and 14 respectively. On the other hand, with 3 per cent of sulphur fused into

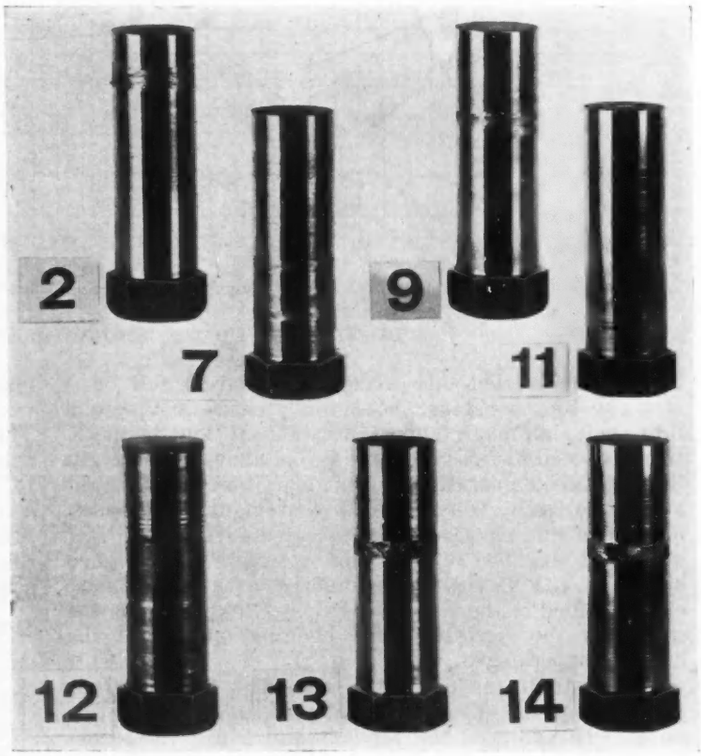


FIG. 19—TEST PINS RUN IN FILM-STRENGTH TESTING MACHINE, SHOWING SCORING EFFECTS FOLLOWING BREAKDOWN OF VARIOUS LUBRICANTS

The Lubricants and the Pressures at Which the Films Broke Are as Follows:

Number	Lubricant	Film-Breaking Pressure, Lb. per Sq. In.
2	Mineral Oil	11,250
7	Soda-Soap Grease	10,750
9	Mineral Oil	7,800
11	Lead-Sulphur Grease	26,500
12	Soda-Sulphur Grease	26,500
13	No. 7 plus 4 Per Cent of Lead Oleate	12,500
14	No. 7 plus 10 Per Cent of Lead Oleate	24,500

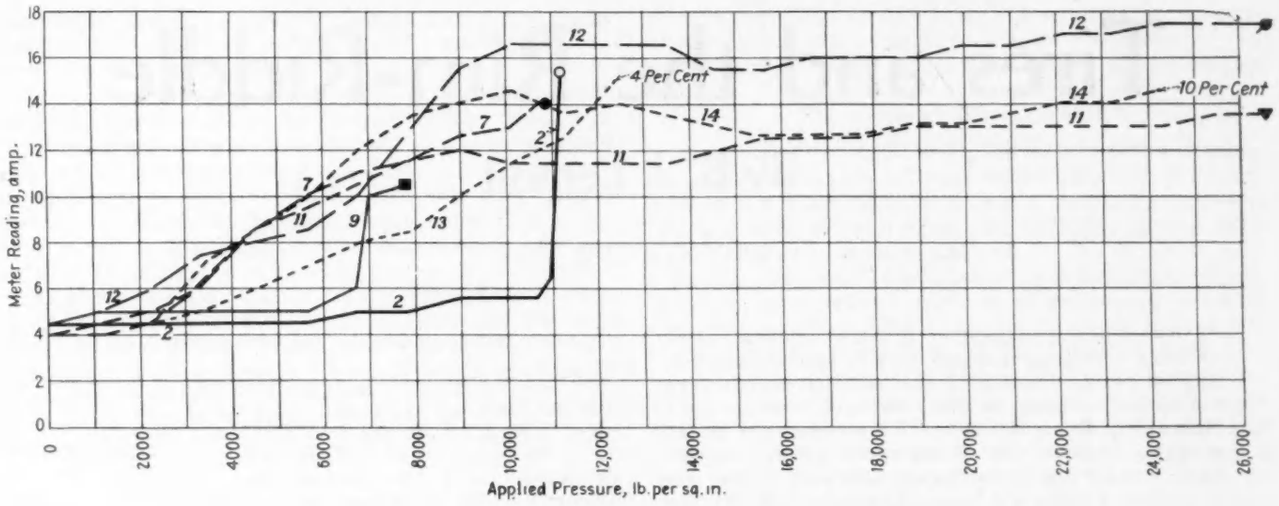


FIG. 20—FILM STRENGTH OF TYPICAL GEAR-LUBRICANTS

These Tests Indicate Performance under Conditions of High Pressures Such as Are Encountered in Rear-Axle Operation. Lubricants Nos. 2, 7 and 9 Failed Respectively at Pressures of 11,250, 10,750 and 7800 Lb. per Sq. In. The Effects of Film Failure of These Three Lubricants and Nos. 11 and 12 on the Test Pins in the Film-Strength Machine Are Shown in Fig. 18

lubricant No. 7, this product, which is none other than lubricant No. 12, withstands a load of 26,500 lb. per sq. in. With the load released, the frictional drag became that of the new pin, the meter reading amperes returning to the original reading for the lubricant before the load was applied, thus showing that no scuffing occurred. Lubricant No. 11 owes its high film-strength to a combination of lead oleate and 2 per cent of sulphur.

For hypoid gears, where the pressures are too great for fluid-film lubrication to be maintained with the use of straight mineral oils, transmission and rear-axle lubricants having a film strength of 25,000 lb. per sq. in. should be used. Yet lubricants containing solid material in suspension are undesirable for ball and roller-bearing lubrication.

On account of the many different conditions under which transmission and rear-axle lubricants are used and because of the many different methods of manufacture, any one detailed specification is not applicable as an indication of performace characteristics. Consumers must necessarily depend upon the individual oil companies to produce a quality lubricant, using for their guidance a viscosity, consistency and film-strength classification to be determined upon and subsequently published in the car manufacturers' instruction books.

Current Automobile and Bus Fuel-Line Temperatures

(*Concluded from p.* 320)

in case of failure of the mechanical pump due to vapor lock. Four of the buses had two carbureters each.

The data obtained are given in Table 6, in which the values represent temperature increases above the atmospheric temperature. It is to be noted that the temperatures in the fuel-tank outlets are not very different from atmospheric, due probably to the location and capacity of the tanks. The average temperature increase above atmospheric at the fuel-pump inlet was 30 deg. fahr., under operating conditions, with a maximum value of 49 and a minimum of 8 deg. During idling the average was 50 deg., with maximum and minimum values of 88 and 14 deg. respectively. Analogous values for vacuum-tank-inlet temperatures are not averaged with these, since they appear to vary considerably depending upon whether the line is full of gasoline or empty. Since the values shown in the table represent the highest readings, those for the vacuum-tank-inlet temperatures are applicable to conditions when the line is empty. This accounts for the decrease in temperature across the vacuum tank observed in most cases.

The average temperature increase above atmospheric at the fuel-pump and vacuum-tank outlet under operating conditions was 35 deg. and on idling 53 deg. The maximum values were respectively 56 and 95 deg., while the minimum values were 15 and 24 deg. The average temperature-increase across the fuel-pump in the case of the four buses equipped with fuel-pump systems was 7 deg.

In those cases where the engine had two carbureters, there was not much difference under operating conditions between the temperatures at the inlet to each. On idling, the rear carbureter (No. 1) seemed to reach somewhat higher values.

On the average, the temperatures found in the buses investigated were lower than those for the automobile fuel systems. This is somewhat surprising, considering the much more limited space under the hood in buses. There is still considerable room for improvement in the design of bus fuel-feed systems, and the suggestions made in connection with automobile systems should be equally applicable to buses.

Tires and the Rim-Riddle

By B. J. Lemon[1]

Annual Meeting Paper

THE objective method of problem analysis, which aims to replace "I think" with "I know," should be applied to the solution of the automotive industry's rim-riddle. During car life, tire costs average more than thirty times rim costs. This makes rim design a major tire-problem. High speed, safety, appearance, and service focus present attention on automobile rims, wheels, and tires. The history of clincher and flat-base straight-side tires and rims is reviewed.

The English pioneered the well-base rim and decided that its success depends on the nice adjustment of rim dimensions to the requirements of the tire. English and American international standards of drop-center rims seem likely to be adopted. German drop-center rims resemble the English standard and include a safety type of rim. The French drop-center rim and tire are not interchangeable with other European or with American equipment.

In the United States the drop-center rim was first used on Ford and on Lincoln cars. The great change to the drop-center tire and rim by Chevrolet, Chrysler, Willys, Pontiac, Essex, and other quantity-production car-manufacturers in 1929 and in 1930 indicates that previous wariness of adoption has been overcome. Rim, wheel, and tire alterations are under way in proportion to the suddenness and extent of this equipment change.

Methods of putting on and removing both small and large-size tires are suggested. Rim strips, and location of valve holes are discussed and a semi-drop-base rim is described. The tabular data cover present original-equipment tire-and-rim sizes for English, German, French, and American 1931 cars. Rim profiles and dimensions are included. Opinions and experiences of American automobile engineers are given.

The author advances two factors considered essential for the prolonged success of the drop-center rim in America. One factor is that tires shall mount and dismount with the same or with greater ease than that for flat-base rims. The other factor is that tire service and car-operating safety on drop-center rims shall be comparable with or better than past performance.

For light cars the public appears to have accepted the drop-center rim as a step in advance. The years 1931 and 1932 will record car-owner reactions to the rim for larger cars. As an engineering body, honest open-minded analysis of the industry's tire-and-rim problems is certain to lead to a continued improvement of the automobile.

THE procedure in problem-solving in the analytical sciences is (*a*) to collect the facts by making observations with complete honesty and complete disregard of all theories and presuppositions; (*b*) to analyze the data to find what conclusions follow necessarily from them or what interpretations are consistent with them. This is the scientific or objective method.

In trying to solve an industrial problem such as that of the adoption or rejection of a new tire-attachment of which the drop-center rim is an example, it is not as easy as it is in the exact sciences to know, when one has finished, whether one is right or wrong. The rules of the art of tire-and-rim making and testing are not as fully charted as are the laws of physics and chemistry; yet the application of the scientific attitude helps to separate fact from personal opinion, to deduce logical conclusions by analysis, and to adopt not so much a code of rules as an attitude of mind that aims to replace *I think* with *I know*. Based upon these principles, a review of the history and present relationship of tires and rims has been undertaken; and, in particular, a review of that of drop-center rims.

The Rim Is a Major Tire-Problem

No current problem fastens its tentacles on the tire industry with such retarding force as the world-wide riddle of the rim. In one distorted form or another, rims have linked the tire to the wheel of the most forward transportation movement in history. In the past, a question of heated international and interindustrial disagreement, the present situation regarding the rim is more than ever a riddle of riddles.

The rim equipment of the automobile generally lasts during the life of the car; but it is not so with tires. Three sets of tires may be worn out on one set of rims. A tire costs eight to ten times more than a rim. Three tires worn out on a rim have a value, therefore, of from twenty-four to thirty times the rim value. That is the significant reason why tire engineers pay so much attention to rim design as related to tire service.

Every tremendously accelerated development, such as the automobile, is certain to be accompanied by inevitable changes of design. Rims and tires both have failed to escape besetting evils such as a craze for the new, regardless of the true; or a demand for a change for the sake of a change, without consideration for the consequences. Sound and economic engineering should know no such thing as change for the sake of change. It should build upon, not discard, the past. The passing on of our accumulated knowledge, of our experience that is unalterable, of our truths that always remain truths to the generations that follow after, must remain the great signposts of progress in our industry.

Why Rims Are in the Spotlight

New car-speeds that thrill and yet provoke our fears for safety, manufacturing competitions whetted sharp by combinations and recessions, national efforts to pro-

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tect home industries, requirements of low and light weights, of beauty and simplicity, of noiselessness and easy service; these conditions have focused the spotlight of interrogation on the 1931 attachments that hold the pneumatic tire to the automobile wheel. In the confusion, car and tire engineers now grope more than ever, confounded by the riddle in national standards which for years we have confidently hoped might become acceptable international standards. The situation in general is that English-made rims have not been most suitable for American-made tires. French "Bibendum" rims accommodate only French-made tires. German rims take British tires, but are not well adapted to American tires. Table 1 shows the approximate relative extent to which various types of rim are in use on cars, made in the last five years and probably still operating, in some of the more important countries of Europe and in the United States.

TABLE 1—A WORLD-WIDE RIM-RIDDLE IS INDICATED BY THE FOLLOWING ESTIMATES OF THE PERCENTAGES OF TYPES OF RIM USED ON AUTOMOBILES MADE IN THE FIVE-YEAR PERIOD 1926 TO 1931, AND NOW IN USE IN THE COUNTRIES LISTED

	Flat Base, Per Cent	Drop-Center or Well-Base Rims, Per Cent	Metric Bibendum Rims, Per Cent	Clincher Rims, Per Cent
England	35	60	..	5
France	35	5	55	5
Germany	30	50	10	10
Italy	60	25	5	10
Scandinavia	65	25	5	5
Belgium	65	5	25	5
Spain	80	2	10	8
United States	72	25	..	3

American rims have changed so rapidly in types, widths, contour and nomenclature that the novel rim of today is almost in the junk heap of tomorrow. How, then, can the car maker economically service his car or the tire maker know what tire to design that will function on the majority of rims for six months in advance? The situation is so serious that "muddle" paints the present picture much more vividly than "riddle."

Rims and tires represent two industries that do not starve for new ideas but, perhaps, because of them. New ideas in themselves are signs of progress. We need engineers with fresh intellects that are also safe intellects; not safe in the discarded sense of dodging decisions, but in the modern sense of making them and making them right.

Tire-and-Rim History

The straight-side tire came into use in Great Britain and other European countries about 1888. Along with it came the clincher tire and the single-tube tire, all of them receiving trial with the advent of the bicycle. By 1898 the automobile had created a considerable demand for pneumatic tires. As this demand for heavier tires increased, the single-tube tire was rather quickly eliminated by its inferiorities. The straight-side or wired-on tire was not considered practical, chiefly because there was no easy way to get it on and off of existing rims.

The clincher or extensible-bead tire on a one-piece rim appeared to solve the problem, because the tire beads could be stretched over the flanges of the rim. The clincher tire therefore became the standard for the motor car in Europe as well as in America, throughout the period of development and afterward. It continued to be standard in Europe up to the advent of the balloon tire in 1923, and on American light cars up to 1924.

The Clincher Tire and Rim

As to its advantages and disadvantages, the clincher rim, generally made integral with the wheel, although later in a demountable form, was a simple light-weight low-cost rim. It embodied the principle of the fifth wheel, readily acceptable abroad.

In the rim itself, there were few important disadvantages aside from tendencies of early-made rims to rust, due largely to the undeveloped art of rust proofing and to the drawback of the inturned rim-edges which, when bent by road blows, were difficult to restore. The chief objections to the clincher rim were tire disadvantages. The tire was hard to apply and remove, especially in the larger sizes, this being a drawback which was never remedied. As the tire increased in size, the difficulty of stretching the hard-rubber compound in the bead increased. The application of too much power in mounting stripped or broke the beads, particularly of tires in which the bead compound was overcured or had aged and become brittle.

Considerable care was required in applying and removing the clincher tire to avoid pinching the tube either by the applying tools or by the bead itself. If the bead were made to a high tolerance, for easy application, creeping of the tire on the rim followed and, at times, such tires under driving or turning would throw altogether off the rim.

Clincher tires also were subject to a cutting or gouging action of the rim clinch, especially when run at low inflation-pressure. The clincher-tire bead, being extensible, relied on full air-pressure to hold it to the rim. Reduced inflation-pressures, which always occur in service, opened the way for bead rocking and for resulting bead-and-tube cutting and bead throwing, due to axial forces set up by the swerving car. Cutting and breaking above the rim flange were probably the most frequent sources of failure of the clincher casing.

As a result of these shortcomings of the clincher tire, American tire-makers sought some other attachment to hold the tire to the wheel. They turned to the old British straight-side tire, which awaited mainly minor refinements, and a practical rim to popularize it.

Straight-Side Tires and Rims

The straight-side tire has a non-extensible bead that cannot be stretched sufficiently to force it over a rim flange and onto the bead seat of a flat-base rim. To get the straight-side tire on the rim it became necessary to make one of the rim flanges detachable, or else to split the rim transversely so that it could be contracted. Both these types of rim were developed, making the straight-side tire a practical and efficient product.

A small clearance was allowed between the tire beads and the rim base so that tires would easily slide onto and off the detachable-flange type of rim. The beads therefore were not in contact with the rim base all around, and the tire was said to float on the rim. To prevent tube pinching by the toes of floating beads, as well as to protect tubes from spoke heads of wire wheels, flaps came into use.

The major advantages and disadvantages of the straight-side tire on the straight-side rim, as compared with the clincher tire and rim, are as follows:

An ease of application and removal that has become acceptable in America through general usage and familiarity with the various types of demountable rim. A greater tire-security from inextensible steel-cabled beads. A broader rim-base, giving greater air-capacity and more stable car-roadability. A better tire-service due to the elimination of rim cutting, less tube-pinching, and less damage when run deflated.

The straight-side rim is heavier than was the clincher rim, due to heavier flanges and to bolts and lugs for the demountable type. It is therefore more costly. It is made in two pieces, in the detachable-flange type, and this flange sometimes becomes squeaky. The open ends of the detachable flange sometimes allow seepage of water under the bead and, sometimes, if sharp edged, may cut into the bead fabric under severe load.

The transversely split collapsible-rim, unless hinged, may become distorted because of abuse in service. When hinged, it requires a tool to collapse it.

The American flat-base straight-side rim, and the tire for it, have been developed to a high state of perfection. Our great advances in tire design and the resulting immensely increased tire-service have been made, largely, because flat-base straight-side rims have been used over a comparatively long period. Tires fitted to these rims have been reasonably free from those bead and tube troubles that might be traceable to the less practical clincher type of rim attachment.

The Well-Base Tire and Rim

Through the cooperation of the management and the engineers of the Dunlop Co., England, much of the information to follow covering English tires and rims has been made available. This cooperation is gratefully acknowledged.

The drop-center rim, designated "well-base rim" in England, was patented in 1890 by C. K. Welch. The rim, not only standard for bicycles in Europe but also for motorcycles, remained practically dormant so far as automobiles are concerned until the advent of the balloon tire in 1923, when the Dunlop Co. grasped the opportunity to reintroduce the rim in combination with the detachable wheel.

The detachable-wheel well-base-rim combination met the weight and cost objections raised against wood wheels and demountable straight-side rims, first by English and later by Continental car builders; also, it provided a tire-mounting feature quite acceptable to car owners long accustomed to the clincher type of tire. As a result of a well-directed tire-and-rim effort by Dunlop, who controlled tire-and-rim original-equipment in England, 80 per cent of new-model British-cars made in 1926 carried detachable-wheel well-base rims. In 1930, this percentage on British-made cars has increased to be almost 100 per cent.

The usual fears for driving safety were raised against the well-base rim, resulting in the early use of catch beads on the tires and rim filler-attachments at the valve, both of which safety devices have since been removed from British-made tires.

Dunlop engineers early recognized what they still believe to be a determining factor of a successful well-base tire-and-rim combination; namely, the tire-bead construction. They designed a narrow tapered, rather than a wide bead, because of lesser toe-movement during bead rocking, affixed a rubber toe to prevent tube pinching, and adopted a wedge fit on the bead seat

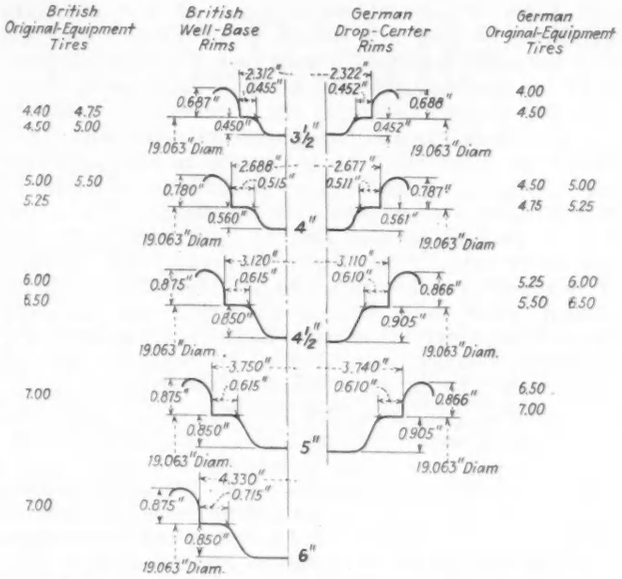


FIG. 1—BRITISH AND GERMAN WELL-BASE TIRES AND RIMS

British Well-Base Rims Are Shown on the Left. On the Right, for Comparison, Are German Drop-Center Rims (Tiefbettfelden). The Two Standards Are Very Similar in Dimensions. The Widths between Flanges Are the Same as the Original Series of American Flat-Base Rims. Dunlop, the Largest-Scale British Rim-Producer, Is Planning to Change to the American Drop-Center Rim Line-up, Shown in Fig. 3. Should the German Support Be Obtained for This Program, Such Support Might Furnish the Necessary Impetus for Establishing a World-Wide Drop-Center-Rim Standard

instead of allowing the tire to float partially, as is the case with the straight-side tire on a rim of the flat-base type. Further, this narrow bead made easy the application of the tire, one bead at a time, to the well-base rim and enabled rims to be used with reasonably shallow wells, thus reducing the possibilities of throw-off of a deflated tire.

The present British well-base rims for automobiles are shown in Fig. 1. The width of these rims corresponds to the widths of the earlier sizes of American flat-base rims; therefore, they are somewhat narrower than the American standard drop-center rims. Because of the increased use of six-ply medium-pressure tires, British tire-and-rim makers, particularly Dunlop, have been impressed with the advantage of somewhat wider drop-center rims required for these extra-ply tires and have made plans, with a commendable spirit of cooperation, to adopt and to put into production and use the series of drop-center rims recently modified and adopted as an American standard by the Tire & Rim Association, Inc. Details of drop-center tire-and-rim equipment for 1931 British-made cars are shown in Table 2.

German Drop-Center Tires and Rims

Through the kindness of the Kronprinz Co. of Ohlings and of Charles S. Crawford, M.S.A.E., chief engineer of Opel Russelheim, Germany, a survey of German rims and tires has been made available for this paper. It is a pleasure to acknowledge this cooperation.

The history of motor-vehicles in Germany discloses the use of a great mixture of makes and types of domestic and foreign-made tires and rims. The German metric-dimension clincher-type of tire and rim lost ground slowly at first but later with increasing rapidity

with the coming of the balloon tire and the drop-center rim in England. Safe, easily mounted, water tight, and affording reduced rotating forces, the drop-center rim

TABLE 2—TIRE AND RIM SIZES USED AS ORIGINAL EQUIPMENT ON 1931 BRITISH CARS

Make of Car	Tire Size, In.	Usual Well-Base Rim, In.
Coventry Victor	4.00-19	3
M. G.	4.00-19	3½
Singer	4.00-19	3½
Triumph	4.00-19	3½
Wolseley	4.00-19	3½
A.J.S.	4.40-19	3½
Armstrong Siddeley	4.40-19	3½
Hampton	4.40-19	3½
Hampton	4.40-19	3½
Horstman	4.40-19	3½
Jewel	4.40-19	3½
Jowett	4.40-19	3½
Morris	4.40-19	3½
Morris	4.40-19	3½
Marendaz	4.40-19	3½
Rover	4.40-19	3½
Standard	4.40-19	3½
Singer	4.40-19	3½
Swift	4.40-19	3½
Lea Francis	4.50-19	3½
Aston Martin	4.50-21	3½
Ford	4.75-19	3½
Rhode	4.75-19	3½
Alvis	4.75-20	3½
Alvis	4.75-20	3½
Crossley	4.75-21	3½
Talbot	4.75-21	3½
Armstrong Siddeley	5.00-19	3½
Hampton	5.00-19	3½
Horstman	5.00-19	3½
Jewel	5.00-19	3½
Lea Francis	5.00-19	3½
M. G.	5.00-19	3½
Morris	5.00-19	3½
Standard	5.00-19	3½
Singer	5.00-19	3½
Trojan	5.00-19	3½
Vauxhall	5.00-19	3½
Alvis	5.00-20	4
Beardmore	5.00-20	4
Singer	5.00-20	4
Morris	5.25-18	4
Rover	5.25-18	4
Wolseley	5.25-18	4
Talbot	5.25-19	4
Alvis	5.25-20	4
Arrol-Aster	5.25-21	4
Crossley	5.25-21	4
Star	5.25-21	4
Whitlock	5.25-21	4
Waverley	5.25-21	4
Rover	5.50-18	4
Wolseley	5.50-18	4
Humber	5.50-19	4
Hillman	5.50-19	4
Morris	5.50-19	4
Standard	5.50-19	4
Armstrong Siddeley	5.50-20	4
Vauxhall	5.50-20	4
Talbot	6.00-18	4½
Beverley	6.00-19	4½
Invicta	6.00-19	4½
Rolls-Royce	6.00-19	4½
Armstrong Siddeley	6.00-20	4½
Humber	6.00-20	4½
Lanchester	6.00-20	4½
Star	6.00-20	4½
Whitlock	6.00-20	4½
Arrol-Aster	6.00-21	4½
Crossley	6.00-21	4½
Armstrong Siddeley	6.50-20	4½
Rolls-Royce	7.00-20	5
Lincoln	7.00-20	5
Lanchester	7.00-21	5

TABLE 3—DROP-CENTER, "SAFETY", AND FLAT-BASE RIMS, DEMOUNTABLE WHEELS AND TIRES, USED ON 1931 GERMAN CARS. THE MOST POPULAR SIZES OF TIRES AND RIMS HAVE 18-IN. AND 20-IN. DIAMETERS.

Name of Car	Rim Size, In.	Rim Type	Tire Size, In.	Type of Wheel
Adler	4 x 18	D.C.	5.25-18	Disc
Adler	4½ x 20	D.C.	5.25-20	Disc
Adler	4½ x 20	D.C.	6.00-20	Disc
Brennabor	4 x 18	D.C.	4.75-18	Disc
Brennabor	4 x 18	D.C.	5.00-18	Disc
Mercedes-Benz	4 x 18	D.C.	5.25-18	Steel Spoke
Mercedes-Benz	4 x 20	D.C.	5.00-20	Steel Spoke
Mercedes-Benz	4½ x 20	D.C.	5.25-20	Steel Spoke
Mercedes-Benz	5 x 21	D.C.	7.00-21	Steel Spoke
Mercedes-Benz	5 x 20	D.C.	6.50-20	Steel Spoke
Hanomay	3 x 19	Safety D.C.	4.00-19	Disc
Horch	5 x 20	D.C.	6.50-20	Disc and Steel Spoke
NAG Protos	4½ x 20	D.C.	6.00-20	Disc
NSU	4 x 18	D.C.	5.00-18	Disc
Opel	3½ x 18	D.C.	4.00-18	Disc
Opel	3½ x 18	D.C.	4.50-18	Disc
Opel	4 x 18	D.C.	5.00-18	Disc
Opel	4½ x 20	D.C.	6.00-20	Disc
Simson	4½ x 20	D.C.	6.00-20	Steel Spoke
Simson	4½ x 20	D.C.	5.50-20	Steel Spoke
Steyr	4½ x 20	D.C.	5.50-20	Disc
Wanderer	4 x 18	Safety D.C.	5.25-18	Disc
DKW	3 x 19	Safety D.C.	4.00-19	Disc
DKW	4 x 18	Safety D.C.	5.00-18	Disc
Mannesmann	4½ x 20	D.C.	6.50-20	Disc
Selve	4½ x 20	D.C.	6.00-20	Disc
Selve	5 x 20	D.C.	6.50-20	Disc
Phanomen	4 x 18	D.C.	5.25-18	Disc
Deutsche Fiat	4 x 18	Safety D.C.	5.25-18	Disc
Deutsche Mathis	4 x 18	Safety D.C.	4.50-18	Disc
Deutsche Mathis	4 x 18	Safety D.C.	5.25-18	Disc
Deutsche Citroen	4 x 18	D.C.	5.25-18	Disc
Aude	30 x 5	S.S.	6.50-20	Disc
Austro Daimler	30 x 5	S.S.	6.50-20	Wire
Craf & Stift	30 x 5	S.S.	7.00-20	Disc
Maybach	30 x 5	S.S.	7.00-20	Disc
Stoewer	26 x 4	S.S.	5.25-18	Steel Spoke

shown in Fig. 1 is standard equipment today on close to 90 per cent of all German-made cars. The present equipment of tires, rims, and wheels for German cars is shown in Table 3.

The drop-center rim in Germany is used exclusively in connection with one-piece detachable-wheels. Demountable rims of any construction have never been popular on German-made cars, and demountable drop-center rims are considered technically impossible. The one-piece drop-center rim is combined easily with steel-disc, steel-spoke, and wire wheels, but not with wood wheels.

Recently, German tire-and-rim engineers have given consideration to shallowing the well of the drop-center rim and to reducing the flange height in close proportion. The shallow well, they state, has one disadvantage; it does not give absolute guarantee against the tire coming off, which can happen when strong axial forces act on a much under-inflated or entirely deflated tire and tube in motion.

The Kronprinz Co. of Germany has developed a "safety" rim which is designed to combine, so far as tire throwing is involved, the advantages of the drop-center with those of the straight-side rim. In the safety rim, both casing and tube are blocked by a number of elevations made by pressing the well of the rim upward toward the tire seat. At these bridges, the tire cannot slide into the well, while, on the valve seat, the sealing

is accomplished by the valve itself, together with the usual tube reinforcement on the valve seat. Table 3 indicates that five German cars are using the safety rim.

The basic idea of the foregoing safety rim, patented in Germany and France, is by no means new in America where attempts have been made to utilize the same general idea in the form of a rim-filler built onto the tube or to function independently of the tube. There is, however, an advantage in having a safety feature, if such a feature is thought essential, incorporated in the rim; namely, that standardized casings and tubes without special construction or dimensions can generally be mounted on the rim.

The bead construction on German tires is such as will fit the ledge of the drop-center rim, as well as the base of the straight-side rim. The bead diameter of the tires is made to fit snugly the drop-center-rim ledge; consequently, tires fit the straight-side rims with a little play". The beads are somewhat reduced in width, curved downward sightly, and provided with a small toe along the inner edge to prevent tube pinching. Special inner-tubes that differ in dimensions from tubes used in straight-side tires are provided for drop-center rims in Germany.

Valves in German-made inner-tubes are straight for both drop-center and straight-side rims. In drop-center rims, the valve comes out of the side of the well. Since occasionally pinching or jambing of the inner tube has occurred, the tendency is to place the valve in the center of the well for future use. The tube for the safety rim carries both straight and bent valves. This tube has very nearly the same dimensions as does the straight-side tube.

Drop-center-rim strips are used only in connection with wire wheels. No rim strips of any kind are used in disc or in steel-spoke drop-center wheels.

French Metric Drop-Center Tires and Rims

The most potential French manufacturer of automobile tires, wheels and rims is the Michelin Co. For years Michelin has held the leadership not only of the tire, wheel, and rim industries in France, but has been responsible for large exports of such French products. The important sizes of Michelin drop-center rims and tires are shown in Fig. 2. The Michelin "Bibendum" straight-side tires and rims, brought out early in 1927 to replace millimeter-dimensioned clincher-tires and rims, established new metric diameter and section standards. Accordingly, these new tires and rims were not interchangeable with the inch standards of European and American manufacture.

At present, about 75 per cent of the cars manufactured in France use Michelin Bibendum metric rims because Michelin will not sell wheels as original equipment without supplying the tires; his price on wheels is so much lower than that of other French wheel-makers that most automobile manufacturers have not escaped buying Michelin tires and rims for their cars. Manufacturers of high-powered French-cars use the English drop-center-rim on wire, disc, wood, and cast wheels. Most of these cars use the English drop-center rim and tires as original equipment.

The Michelin Bibendum metric rim has low flanges and is of one-piece construction with a drop center that is deepest at the valve hole but which decreases gradually to a flat surface at the opposite side of the rim. The purpose of the eccentric well in the rim is to

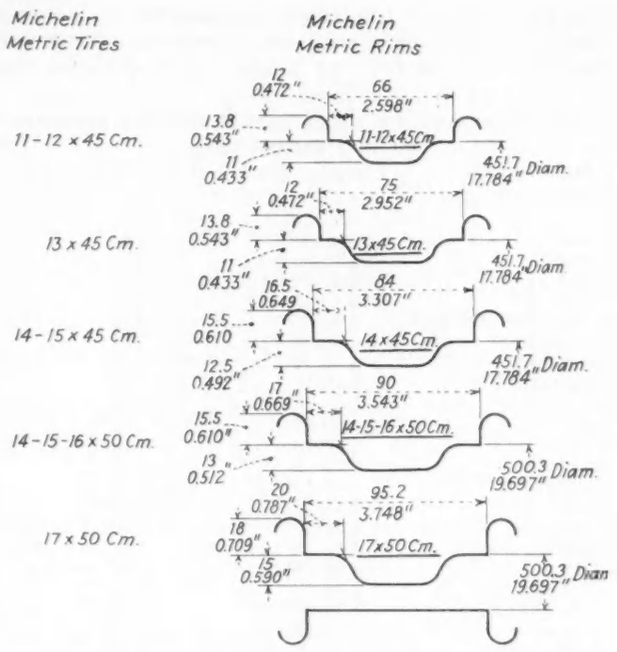


FIG. 2—MICHELIN, FRENCH, METRIC TIRES AND RIMS

Profiles of French-Bibendum Rims, Metric and Inch Dimensioned, as Made by the Michelin Co., the Largest Tire, Wheel and Rim Producer in France. Bibendum Rims Are Single Piece and Eccentric with Respect to the Drop-Center Depression. The Well Is Deepest at the Valve Hole, Decreasing Gradually in Depth to a Flat Surface at the Opposite Side of the Rim. Michelin Straight-Side Tires, Metric Dimensioned, Are Shown as Recommended for Bibendum Rims

reduce the possibility that the tire will "jump" the rim. An additional safety feature is the employment of a thick rubber-pad at the base of the valve to block the beads from the well at that point. The tire valve and valve pad are said to balance the reduced weight of the depressed portion of the rim.

That the Michelin rim holds a deflated casing probably as well as does the flat-base rim is not denied. That it does not prevent the possibility of peripheral creeping of the casing is generally conceded. Moreover, this eccentric rim is more difficult to manufacture than is the full drop-center rim. The non-standard Michelin dimensions make interchangeability of products from other countries impossible and are contrary to the present tendency to standardize sizes and types for the convenience of the motor trade.

The reaction from the car manufacturer, who equips his car with non-interchangeable rims and tires, and from the public, which desires and expects to avail itself, for replacement, of tires of all makes stocked throughout the world, is becoming apparent. Once almost completely in control of the tire-and-wheel business of France, and the dictator of prices and sizes in many foreign markets, the Michelin prestige in the last three years seems to be suffering a decline. Business grows more complex as the world grows smaller, and the lightening factor in this complexity is international simplification and standardization.

Ford Adopts Drop-Center Steel-Spoke Wheel

In 1925, the Ford Motor Co. began experimenting with the drop-center type of rim already well established in England, finally going into production on the

4.40-21-in. tire and the 2.75 x 21-in. drop-center steel-spoke wheel early in 1926.

An enormous amount of creditable development work was carried out by the Ford Co. and by their tire suppliers to produce the successful adoption of the steel-spoke wheel in large production. The problem of turning out a true welded-spoke wheel must have been at that time comparatively very costly in itself. Tire makers rebuilt tire beads many times to assure proper mounting and fit on the rim shoulder. The contour of the rim was carefully designed and studied. Inner tubes experienced a similar revolution before a combination product was found that would be satisfactory for the new drop-center rim and for the flat-base rim having the same diameter.

Educational work, starting in the larger metropolitan centers, was carried on to guarantee a proper knowledge of application and removal of drop-center tires by car and tire dealers and by car owners. All of this work was carried out in a fine spirit of cooperation and to such a successful degree that the slightly widened original rim-profile and type of wheel have been continued in use to the present time on Ford cars. Further, the original rim-section was adopted as a standard by the Tire & Rim Association, Inc.

Lincoln Selects Drop-Center Rim

Early in 1928, the Lincoln Division of the Ford Co. also successfully applied the principle of the drop-center rim to the steel-spoke wheel, and made this type of wheel standard on the Lincoln car. Therefore, the smallest and one of the largest American cars were the first to be equipped with drop-center rims. The rim applied to the Lincoln was 20 x 4.00 in. of the profile shown in Fig. 3 with the dash base-line. It is still in successful operation on this car, this rim profile being accepted also as an American Tire and Rim Standard, though later modified in well depth. A 7.00-20-in. tire and tube were developed to function satisfactorily on both the 4.00-in. drop-center rim and the 5-in. flat-base rim.

For the Lincoln wheel, designing a properly fitting and functioning casing and tube presented a different and perhaps a more difficult problem than for the Ford wheel. The larger tire-section and wider bead-foot tended to produce more movement at the toe of the bead, and therefore more abrasion of the tube at the point of contact. Several months of rather intense work were required to find a solution. Besides a properly designed tube and bead, one important improvement was effected by increasing the diameter of the rim ledge to reduce rocking by affording a snugger bead-fit. This improvement was later incorporated in other American drop-center rims.

The problem of designing large-size tires for the drop-center rim was further aggravated by the fact that other high-class cars were using the same tire-size on detachable-flange flat-base or split-type rims, so that the amount of drop of the bead toe was limited to a design that could be pushed on and pulled off the flat-base rim easily.

It seems to be of passing interest to speculate on the advantages of pioneering the drop-center steel-spoke wheel on Ford cars in America. It is doubtful whether any material saving was made either in weight or cost in the early wheel-equipment. Car appearance certainly was improved, particularly with the advent of the wheel of smaller diameter. A better-balanced, truer and perhaps stronger wheel was obtained. Tire mounting also was facilitated after the knack was acquired.

The location of the spare wheel-holder on the rear or side of the car was such as to encourage its use as a tire-changing stand. Casing life was certainly not reduced, and it may have been somewhat increased when used on the drop-center rim. Tubes, on the other hand, were sometimes cut and, occasionally, valve stems pulled out of tubes used on drop-center rims when extended deceleration was effected on a flat tire. Beads to a limited extent were kinked or broken during the process of applying and dismounting the casings by inexperienced owners. Tire eccentricity occasionally resulted from improper seating of the beads on the rim ledge. To correct this, lines were placed on the casing above the bead as guides to concentricity.

Drop-Center Tire-and-Rim Progress Slow

American car-makers generally have been wary of choosing the drop-center rim as standard equipment. During the last year, and impulse to try out drop-center

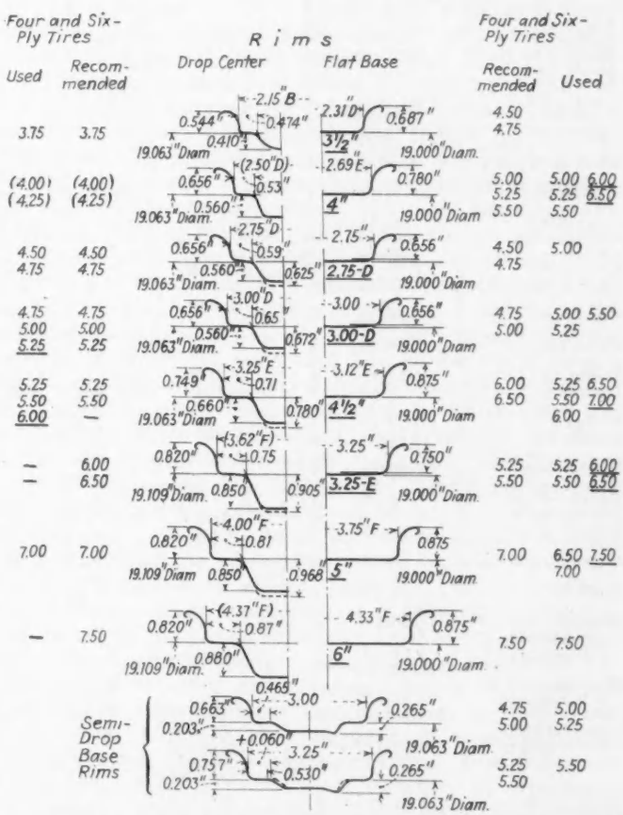


FIG. 3—AMERICAN DROP-CENTER AND FLAT-BASE TIRES AND RIMS

Comparison of American Drop-Center and Flat-Base Rims Listed in the Order of Increasing Widths between Flanges. Two Sizes of Semi-Drop-Base Rims Are Shown in the Lower Center View. The Sizes of Tires in Use on, and Recommended for, the Three Types of Rim Are Listed Opposite Each Rim Type and Size. Rim and Tire Sizes in Parentheses Are Not Yet in General Production. The Tire Sizes That Are Underscored, While They Are in Use on the Rims Indicated, Are Not Considered by Some Engineers as Being the Best Practice from the Viewpoints of Tire Width to Rim-Width Ratio, of the Flange Height and of the Relation of Tire-Bead Strength and Width to Rim-Bead-Seat Width. The 19-In. Rim-Diameter Is Shown for Dimensional Purposes. The Solid Well-Bottom Lines Indicate the July, 1930, Standard Depths. The Dash Lines Show the Former Standard Depths

rims has been felt generally throughout the automotive industry. Early in 1929 Chevrolet adopted the rim; first as optional and later as standard equipment. Chrysler, Plymouth, DeSoto, Essex, Dodge, Willys, Oakland, Olds and other makers chose much the same method of introduction; and Austin, our smallest car, came out in 1929 with the drop-center rim as standard equipment. The tire-and-rim equipment used on American cars at the beginning of 1931 is shown in Table 4.

TABLE 4—TIRES AND RIMS USED AS ORIGINAL EQUIPMENT ON AMERICAN CARS; JANUARY, 1931.

Car and Model	Tire Size, In.	No. of Plies in Tire	Rim Size and Type: Flat-Base or Semi-Drop-Base (SDB) Rims, In.	Rim Size and Type: Drop-Center Rims and Wheels
American Austin	3.75-18	4	..	2.156 D.C. Disc and Wire
Auburn 6-85	5.50-18	4	4	
Auburn 8-95	6.00-18	4	4	
Auburn 125	6.50-18	4	4	
Auburn 8-98	5.50-17	4	4	
	6.00-17	4	4	
	6.50-17	4	4½	
Buick 8-50	5.25-18	4	4	
Buick 8-60	5.50-19	4	4 and 4½	
Buick 8-80	6.50-19	4	4½	
Buick 8-90	6.50-19	6	4½	
Cadillac V-8	6.50-19	6	5	
Cadillac V-8	7.00-18	6	5	
Cadillac V-12	7.00-19	6	5	
Cadillac V-12	7.50-18	6	6	
Cadillac V-16	7.50-19	6	6	
Chevrolet	4.75-19	4	2.75	3.00 D.C., Wire
Chrysler 6	5.00-19	4	3.00	3.00 D.C., Wire
Chrysler 66	5.50-18	4	4	
Chrysler 70	5.50-18	6	4	
Chrysler 8	5.50-18	6	4 and 3.25	
Chrysler Imperial 8	7.50-17	6	5	
Cord	7.00-18	6	4½	
Cunningham	7.00-20	6	5	
DeSoto 6	5.00-19	4	3.00 SDB	3.00 D.C., Wire
DeSoto 8	5.25-19	4	3.00 SDB	3.00 D.C., Wire
Dodge 6	5.00-19	4	3.00	3.00 D.C., Wire
Dodge 8	5.50-18	4	4	
Duesenberg	7.00-19	6	5	
Durant 6-12	4.75-19	4		3.00 D.C., Wood and Wire
Durant 6-14	5.00-19	4	2.75 and 4	
Durant 6-17	5.50-19	4	4	
Essex Super-Six	5.00-19	4	4	3.00 D.C., Wire
Ford "A"	4.75-19	4	..	3.00 D.C., Wire
Franklin 125	6.50-19	4	4	
Franklin 132, 5 Passenger	6.50-19 (Standard)	4	4	
Franklin 132, 5 Passenger	6.50-19 (DeLuxe)	4	4½	
Franklin 132, 7 Passenger	6.50-19	6	4, Standard Model; 4½, De Luxe	
Gardner 136	5.50-18	4	4	
Gardner 148	5.50-19	4	4	
Gardner 158	6.00-18	4	4½	
Graham Standard 6	5.50-18	4	3.25; 3.25 SDB	
Graham Special 6	5.50-18	4	3.25; 3.25 SDB	
Graham Standard 8	6.00-17	4	3.25; 3.25 SDB	
Graham Special 8	6.50-18	6	4 and 4½	
Hudson Greater 8	5.50-18	4	4	
Hupmobile S. and L.	5.50-19	4	4	
Hupmobile C	6.00-19	4	4½	
Hupmobile H. and U.	6.50-19	6	4½	
Jordan Standard Line 70 and 80	5.50-18	4	4	
Jordan Great Line 90	6.00-18	4	4	
Jordan Speedway	7.00-18	6	4½	

TABLE 4—TIRES AND RIMS USED AS ORIGINAL EQUIPMENT ON AMERICAN CARS; JANUARY, 1931 (*Concluded*)

Car and Model	Tire Size, In.	No. of Plies in Tire	Rim Size and Type: Flat-Base or Semi-Drop-Base (SDB) Rims, In.	Rim Size and Type: Drop-Center Rims and Wheels
Kissel 6-73 and 8-95	6.00-18	4	4½	
Kissel 8-126	7.00-18	4	4½	
La Salle	6.50-19	6	5	
La Salle	7.00-18	6	5	
Lincoln	7.00-19	6	5	4.00 D.C., Wire
Marmon 70	5.50-19	4	4	
Marmon 88	6.50-19	6	4½	
Marmon DD	7.00-18	6	5	
Nash 6-60	5.00-19	4	3.00; 3.00 SDB	
Nash 8-70	5.25-19	4	3.00; 3.00 SDB	
Nash 8-80	5.50-18	4	3.25; 3.25 SDB	
Nash 8-90	6.50-19	4	5	
Oakland	5.50-18	4	3.25 SDB,	3.25 D.C., Wire
Oldsmobile	5.25-18	4	4	3.25 D.C., Wire and Wood
Packard 826 and 833	6.50-19	6	4½	
Packard 840 and 845	7.00-19	6	5	
Peerless Standard 8	5.50-19	6	4	
Peerless Master 8	6.00-19	6	3.25	
Peerless Custom 8	6.50-19	6	3.25	
Pierce-Arrow C	6.50-19	6	4½	
Pierce-Arrow A and B	7.00-18	6	5	
Plymouth	4.75-19	4	3.00	3.00 D.C., Wire
Pontiac	5.00-19	4	3.00	3.00 D.C., Wire
Reo 125	6.50-17	6	3.25 and 4½	
Reo 130	6.50-18	6	3.25 and 4½	
Reo 135, Royale	6.50-18	6	3.25 and 4½	
Reo 152, Royale	7.00-18	6	5	
Rolls Royce	7.00-20	6	5	
Ruxton	6.00-19	6	4	
Studebaker 6 and Dictator 8	5.25-19	4	4	
Studebaker Commander 8	6.00-19	6	4	
Studebaker President 8	6.50-19	6	4½	
Stutz LA	6.00-19	6	4½	
Stutz MA	6.50-20	6	4½	
Stutz MB	7.00-20	6	4½	
Viking	6.00-18	6	4 and 4½	
Willys 97	5.00-19	4	..	3.00 D.C., Wire and Wood
Willys 98-D	5.00-19	4	..	3.00 D.C., Wire and Wood
Willys 8-80D	5.50-19	4	..	3.25 D.C., Wire and Wood
Willys 66D	6.00-19	6	..	3.25 D.C., Wire and Wood
Windsor 6-69	5.25-19	4	4½	
Windsor 6-75	5.50-19	4	4½	
Windsor 8-85	6.00-19	4	4½	

Why were American car-engineers wary of the drop-center rim? They had accepted many other car features that had their inception abroad. Engineers are human and conservative. In general, conservative humanity is rightfully afraid of nearly everything it has not tried, and the effect of which it cannot foresee. Again, American engineers were well satisfied with the flat-base rim, and the excellent tire-service rendered on that type of rim.

Economy appears to have been another cause for the slow progress of the drop-center rim in America. The wood wheel—first with clincher rim, and then with demountable flat-base rim—has been and probably is today our cheapest wheel. However, it is a type of wheel which seemed to offer the greatest difficulties in adapting it to the drop-center rim.

The disc wheel, next to the wood wheel in order of costs and for a time widely used on American cars, does not appear to have received its merited consideration as a carrier of drop-center rims, in spite of foreign experience. Disc wheels seem to have suffered from an inferiority complex in recent years, and cast wheels never reached a productive status in America. Both types can be combined readily with the principle of the drop-center rim, and it would not be at all surprising if 1931 witnessed the extended use of both types of wheel with drop-center rims.

The wire type of wheel, until recently our most expensive extra-cost type, we have considered best suited for the depressed-base rim. The small production of the wire wheel in the nipple-spoke form and a complicated patent situation undoubtedly retarded development and accounted for high costs over a long period. However, the last two years have witnessed stimulating absorptions and combinations of wheel producers, resulting in greatly increased development and production activity and corresponding reduced manufacturing costs. Therefore, the stage is set properly today for changing to a drop-center scene with the wire type of wheel as the lead-off performer.

In my paper on Balloon Tires for Use with Drop-Center Rims,[2] the prediction was ventured that confusion would result from an early widespread adoption of the drop-center rim. "Confusion hath made his masterpiece" in this winter's avalanche of the application of the drop-center rim to American cars.

Five-Year Debate on Well-Depth

Experimental standards were set up by the Tire and Rim Association for passenger-car drop-center rims in January, 1925. The five-year interim has witnessed numerous alterations in these standards with respect to the rim sections themselves, the heights and types of flanges, the widths and diameters of bead seats, and the angle of slope and depth of the well. However, no one of these dimensions has provoked such widespread disagreement and heated debate as that of the proper depth of well.

Space is not available, nor are the interests of the Tire and Rim Industries advanced by a chronicle of the well-depth controversy. The direct result of experience and experiment, both in America and abroad, has brought about in general an appreciable shallowing of the drop-center portions of all sizes of rim, as indicated in Fig. 2 in which the latest recommended-practices adopted in July, 1930, are shown by full-line contours of the well for comparison with standards in force immediately previous to that date, indicated by dash-line contours of the well.

From the tire viewpoint the July, 1930, well-depths are considered minimum for satisfactory tire application and removal. The flange heights are as low as are thought to be good practice for satisfactory bead-anchorage. The rim-bead seat-widths are minimum for the accommodation of four and six-ply tires in the sizes recommended. The lateral slope of the well of 25 deg. is fixed by past experience as the favorable angle at which existing inflations will force the beads out of the well into the proper position on the ledge. The rim-bead seat-diameter is fixed as correct for tight bead-fit to prevent rocking and tube chafing.

The question of well depth is also coupled in a very important way with the width of the well at the bottom. Car manufacturers who produce several models of limited weight-differences sometimes wish to adapt one wheel to two or more models, but to use different rim-and-tire sizes. Therefore, it is economically important that at least two adjacent sizes of drop-center rims be mounted on the same felloe. To accomplish this, optional contours for the corners of the well bottoms have been agreed upon to facilitate mounting on the same felloe, as well as to accommodate the widths of spokes of wood wheels.

American Tire-Beads

The bead of the present American drop-center rim straight-side tire is made up quite generally of a rounded-bundle type of steel wires, stretched, taped, and imbedded in rubber that becomes semi-hard during the curing of the tire. The apex of the semi-hard rubber above the wire bundle, if this construction is employed, must be retained below the level of the top of the rim flange to guard against flexing movements extensive enough to crack the rubber or loosen it from the surrounding fabric. About this steel and semi-hard rubber, the plies of the casing carcass are anchored to form the bead proper. This bead must be protected at its heel and above by chafing strips; at its toe, when designed for drop-center rims, it usually carries a tongue of varying lengths of firm elastic rubber to provide a velvety contact with the inflated tube at the rim shoulder. The whole construction of passenger-car tire-bead, particularly the toe, has been designed to be manipulated freely onto a drop-center rim and not pried and twisted over the rim flange by a 2-ft. bar in the hands of a muscular mechanic. Granted that the bead wires may resist such treatment, the extreme pressure kinks the wires and breaks the adhesion between the wire and the rubber, and results in separation, chafing and ultimate bead-failure.

The shape of the bead foot, between the heel and toe, varies in American manufacturing practice. On some tires the foot of the bead is quite flat; on others, it tapers downward. Due to the need for fitting the same size of casing to both flat-base and drop-center rims, the degree of bead taper is limited to a bead-foot and toe of such shape as can be pushed on and off detachable-flange flat-base rims. Tapering the bead puts it under compression when the tire is inflated on the drop-center rim, and tends to reduce bead-toe movement.

A bead with a tapered foot and a pronounced soft toe seems to offer no increased resistance, from the well-depth viewpoint, to mounting on a drop-center rim. The soft toe may slightly increase bead-drag when the last 10 in. of beads are flipped over the flange. If a pronounced taper is used, difficulty is experienced sometimes when mounting on a flat-base rim. A compromise to afford some bead compression, some rubber at the toe, and still provide reasonably satisfactory ease in mounting on both types of rim, appears to be good practice. Good tire and tube service may readily be sacrificed to easy as well as to difficult mounting. Satisfactory tire-service depends on a nice adjustment of rim dimensions and tire constructions.

Applying Tires to Drop-Center Rims

The methods of applying tires to American drop-center rims are not and probably will not be made entirely uniform, because all makes of tire do not have the same bead-construction and diameters; all rims of

[2] See THE JOURNAL, June, 1926, p. 630.

the same nominal size do not at present have the same well depth and profile; and those who apply tires in the factories and in the field are not all taught to use the same systems of application. The adoption of uniformity, nevertheless, is highly desirable and steps are being taken to set up a uniform recommended practice of putting on and removing drop-center-rim tires.

Applying tires to and removing them from drop-center rims can be accomplished in two ways. First, by mounting and removing both beads at a time; second, by mounting and removing one bead at a time.

A 4.75-in. four-ply tire-section with a flat or slightly tapered bead can be mounted easily by hand, using no tools on the old standard 3.00-in. rim with a 0.672-in. depth, by the two-beads-at-a-time method. The same 4.75-in. tire on the same rim-section but with a well depth of 0.56 in. can be mounted less easily by hand, two beads at a time, but can be applied more readily one bead at a time. A six-ply 4.75-in. tire, because of its increased stiffness, mounts correspondingly harder on both depths of well. The next larger section, 5.00-in. four-ply and six-ply tires mount with slightly greater difficulty than the 4.75-in. four-ply and six-ply tires. The 5.25-in. four-ply and six-ply tires are still harder to mount.

To take care of this variation in ease of mounting and particularly of removal, which is the more difficult of the two operations, one or preferably two tire-tools, 8 to 10 in. long, may well be considered as necessary equipment for tire changes in the field, and it is recommended that car makers give serious consideration to furnishing properly designed tools with their cars. Further, to secure satisfactory mounting of all sections of tires designed to be used on one size of drop-center rim, it is highly important that the well depth and other dimensions of this rim be designed for the practical application and service of the average tire and not for the smallest most flexible tire.

The application and removal of the larger-size tires, such as the 7.00-in. six-ply section, are practically always made one bead at a time, and tools having a length up to 12 in. are recommended.

Production Mounting Discussed

The ease with which the smaller sizes of tires can be applied to their proper size of drop-center rims by factory workmen who have acquired the knack is a revelation. The speed of application varies from 60 to 120 tires per man-hour, depending on the operations included in the mounting procedure. In some plants, applying a rim strip over the spoke heads is part of the mounting operation; in others, bouncing the tire to seat the beads or applying an inflating chuck to the valve stem are operations included.

Good factory-practice is to use a rigid waist-high stand to which is affixed, at varying angles from the horizontal, a dummy hub to fit the wheel on which tires are to be applied. This hub carries a dummy hub-bolt or other device to lock the wheel against rotation during application. The wheel is placed on this hub with the valve hole at the top or bottom, depending on the mounting procedure employed. When used, the rim strip is applied in the base of the well and is cemented down, particularly at the ends abutting the valve hole.

The casing, with tube enclosed and valve at the balance mark, is placed on the wheel with the valve in the valve hole, for small-size tires, and one or both beads, depending on the method employed, pushed down hard into the rim well. Working both ways around the tire from the valve stem, the beads are pressed together, as for the two-bead method, and down into the rim well until both beads are forced over the rim at a point diametrically opposite the valve hole. Some operators first push the beads into the well, at a point opposite the valve hole, this being a slightly easier but more complicated method, and then work both ways around the tire, forcing the last section of bead over the flange at the valve hole.

The method of mounting one bead at a time is, for small tires, to insert the valve into the valve hole, push one bead of the casing over the flange and into the well of the rim, and flip this bead over the flange all the way around, working both ways from the valve hole; then to raise the casing and push the second bead over the flange at the top of the wheel and down into the well. Working both ways around the tire from the valve stem, push the second bead over the flange, at the same time pulling forward on the casing at a position diametrically opposite from where the hand pressure is applied against the bead. When both beads are over the flange, the valve locking-nut is screwed on and the tire raised so that the beads and tube adjust themselves on the rim. Air pressure is then slowly applied, making certain that the beads are blown into their proper seating position on the rim.

Beads that catch or freeze on the side of the well or on the shoulder of the rim can be detected by inspecting the uniformity of the bead line on the tire, just above the rim flange. An improperly seated bead will cause tube pinching eventually and a tire wabble that will show up later by a jumpy road-action of the wheel.

The employment of tire tools to roll the tire beads of small tires over the rim flanges is restricted generally to the application of the last 12 to 18 in. of unseated beads. Extreme care should be exercised neither to pinch the tube nor to tear the bead toe by the tools or the rim flanges. When extra-ply or oversize tires are difficult to apply, a thin coating of talc applied for a distance of about a foot on the toe of one or both beads greatly facilitates ease of applying tires to the drop-center rim.

The amount of air in the tube directly affects the ease of application and removal of casings from drop-center rims. The lower the air pressure is, the better is the result provided that the tube is not so far collapsed as to catch and remain trapped under the tire beads. The right amount of air has been used when the tube shows a distinct buckle at the bottom when held in a vertical position. The temperature of the casing also has an important bearing on ease of mounting, a cold tire being much more rigid and inflexible than a warm tire, and consequently harder to apply.

Lubrication of the tube by the application of talc facilitates easy application by reducing friction between the tube and the inside of the casing.

Mounting in the field either by the car owner or at a service station follows the same general procedure, except that the operation usually is performed when possible on the spare-tire carrier of the car or on the floor.

Dismounting Tires from Drop-Center Rims

To take off American small-size tires from drop-center rims, remove the valve cap and lock nut, completely deflate the tube by removal of the valve's in-

sides if necessary and push the valve stem back through the rim hole into the casing. Then press the sides of the tire together and the beads into the well, beginning at the top and working both ways around the tire for approximately 12 in. on each side of the valve. At the point opposite the valve, pull both beads over the rim flange; or, using a tool, lift one bead over the flange at a point opposite the valve, taking care that the tool does not pinch the tube. The second bead can then be lifted over the flange, care being exercised to tuck the tube into the casing to prevent interference.

The application to and removal of the larger-size tires from drop-center rims differs somewhat from operations satisfactory for small-size tires. Large sizes are always put on or taken off one bead at a time. The accompanying illustrations, Figs. 4 to 9, depict the important steps of applying and dismounting tires as recommended by the Lincoln Motor Co.

Drop-Center Rim-Strips

Because American drop-center rims are almost invariably used with the wire or steel-spoke wheel, a fabric or composition rim-strip has come into use to cover the spoke heads in the bottom of the well. These strips, which gage from 0.020 in. to 0.040 in. thickness are cemented into the rim by the car producer when the original equipment tires are mounted. The purpose of a rim strip is the same as was the flap on flat-base rims and with the old-type nipple-spoke wire-wheels; namely, to protect the tube from damage by sharp, rough, loose or raised spoke-heads.

The art of wire and steel-spoke-wheel manufacture has made such advancement in the last two years that spoke heads are not as sharp or as rough as formerly if reasonable care is exercised in production and inspection. This improvement has convinced some car producers that rim strips in drop-center wire-wheels can be left off when care in removing metal burrs from spoke heads is exercised. On wood wheels with drop-center rims, as now made, the elimination of rim strips is considered as yet questionable practice. Some tire makers also sanction rim-strip elimination from approved types of wheel. Rim strips, when eliminated, reduce wheel costs slightly and permit easier tire mounting and dismounting both at the production line and in field-replacement service.

Location of the Valve Hole

For a number of years English and Continental makers have located the valve hole in the side of the well, as in Fig. 10, so that the straight valve-stem protrudes outward at an angle rather than vertically in the center of the well, which is the present American practice. There seem to be some important advantages in favor of the English method. If the nipple-type small-spoke wire-wheel is used, the vertical valve-stem is difficult of access for tire inflation, as shown in Fig. 11.

American cars that use the drop-center rim have applied this rim generally to the large-spoke type of wheel. Because of the larger size and additional strength of the steel spoke, fewer spokes are required. Consequently, there is correspondingly greater accessibility to the vertical valve-stem with the steel-spoke wheel. To date there have been no serious handicaps to inflation of the vertical valve in the American steel-spoke wheel; however, since wheel diameters are decreasing and the distance between the brake drum and the rim well is becoming correspondingly narrower, it appears advantageous to consider the adoption of the side valve shown in Fig. 12, at least for 18-in.-diameter drop-center wheels. Should 17-in.-diameter wheels be fitted with drop-center rims, the side valve or an angle type of valve will be almost a necessity. The laterally placed valve-stem is superior for disc wheels in that it does not require so sharp a curve in the disc necessary for the vertical valve.

Another advantage of bringing the valve through the

APPLYING LARGE-SIZE TIRES TO THE DROP-CENTER RIM

Fig. 4—The First Operation Is to Lay the Wheel on the Floor with the Hub Cap Uppermost. Inflate the Tube So That It Is Just Rounded Out But Not Expanded, and Place the Tube in the Casing. One Bead Is Hooked Over the Rim Flange, Pushed into the Well and Held in That Position by Foot Pressure. This Bead Is Then Worked in Both Directions Over the Rim All Around With a Tire Tool

Fig. 5—The Second Operation Is, If Necessary, To Tuck Back the Tube in the Casing. Catch the Second Bead Over the Rim Flange, Force It Down into the Well and Hold It There by Foot Pressure. Working in Both Directions With a Tool, Gradually Force the Bead Over the Rim All Around and Take Care Not to Pinch the Tube

Fig. 6—The Third Operation Is To Rotate the Wheel Inside the Casing Until the Valve Comes Through the Valve Hole. Screw Down and Tighten the Rim Nut. Rotate the Casing on the Tube and Rim Until the Balance Mark Is at the Valve Stem. Inflate Gradually, Making Certain That the Beads Seat on the Rim Evenly All Around on Both Sides

side of the rim is that all tubes for drop-center rims can be equipped probably with the same type and length of valve stem, regardless of the wheel type or rim diameter. Further, English experience records little tube-trouble due to valve pulling when tires are run deflated. Perhaps the lateral location of the valve is beneficial in this respect. Standards were set up by the American Tire and Rim Association, Dec. 11, 1930, to provide lateral valve-hole location and dimensions when so desired in American drop-center rims.

A Semi-Drop-Base Rim

The Motor Wheel Corp. has developed and is in production on two sections of what might be called a modification of the drop-center and of the demountable flat-base rim, known as the semi-drop-base split-rim. For this new rim is claimed the advantages of the full drop-center rim without the disadvantages. The two sections shown in the lower center of Fig. 3 are semi-drop-base rims.

The bead-seat diameter of this type of rim is above the nominal to give the snug concentric tire-mounting feature of the full drop-center rim. The widths between flanges are the same as the dimensions of the corresponding drop-center rims. Lower material-costs are reported possible for the semi-drop-base rim through the use of strip stock. Inventories are kept down therefore by avoiding a special-section rim. The semi-drop-base split-rim, demountable at the felloe, is estimated to cost less and provide a more satisfactory assembly on the felloe than does a full drop-base rim demountable at the felloe.

The drop in the rim base of the semi-drop-base rim helps collapse and also facilitates the assembly of the tire on the rim. The weight of the 19 x 3.00-in. semi-drop-base rim and felloe parts is 6 lb. lighter per set than is the 19 x 4-in. flat-base rim and felloe, and this weight-differential is said to increase as rims in wider sections are compared.

The semi-drop-base split-rim is used successfully by a number of large-scale car-producers in the 3.00 in. and the 3.25-in. rim-sections for tires up to and including the 5.50-in. section. Developments are under way for additional rim sections to accommodate all sizes of tires.

Engineering Opinions Stated

The large majority of American automobile-engineers will get their first year's production and service experience with drop-center tires and rims in 1930 and 1931. Therefore, it is of interest to review some of the opinions that they today express concerning this equipment.

While an abundance of enthusiasm for the acceptance of the new method of holding the tire to the wheel is apparently lacking, the trend today is strong to the drop-center-rim wire-wheel. One engineer states that the increased width of drop-center rims over corresponding flat-base rims results in a larger air-volume without increase in weight or cost, produces greater tire and car stability, and gives the appearance and effect of using the next-size-larger tire.

I believe that these advantages of appearance and stability are undoubtedly well worth considering but I doubt that, from the tire-service viewpoint, an increase in tire width by unduly spreading the beads, or an increase of air volume by hollowing the rim, will materially increase the tires' carrying capacity and service.

For a number of years, tire makers have been divided as to the effect of rim width on tire service. Some hold briefs for the wide rim, others for the narrow rim. Therefore, it seems safe to assert that neither side has proved its contention to the confusion of the opposition, so many are the variables entering into the road performance of tires. Tire engineers feel rather certain that, to produce good riding-quality, a diminished side-sway, and a good load-carrying ability

REMOVING LARGE-SIZE TIRES FROM THE DROP-CENTER RIM

Fig. 7—The First Operation Is to Lay the Wheel on the Floor With the Hub Cap Uppermost. Deflate the Tube Completely. Remove the Rim Nut and Walk on the Tire To Loosen It From the Rim

Fig. 8—The Second Operation Is To Press Down the Top Bead with the Knee and, at a Point Opposite, Insert a Tool between the Bead and the Rim Flange Just Far Enough To Secure a Leverage on the Bead. One Portion of the Bead Must Be in the Well before the Opposite Portion Can Be Lifted Over the Flange. Work the Top Bead Off All Around, and Push the Valve Back into the Casing

Fig. 9—The Third Operation Is To Stand the Wheel Upright So That a Section of the Second Bead Is in the Well at the Bottom. Insert a Tool Between the Bead and the Rim Flange at the Top, and Pull the Casing from the Wheel

in the tire, rim-section widths should range between 50 and 60 per cent of tire-section widths. But examples are not wanting of very successful installations of tires and rims that flagrantly under step such ideal ratios.

Today, from the viewpoint of increased tire-service, rim-flange heights are considered to play a more important role than do rim widths. Flange heights afford the only lateral support received by the tire, and that support must be sufficient to protect the bead wires and the surrounding embedment of semi-hard rubber. Flange heights are assuming added importance, as related to the well depths of drop-center rims, an importance which cannot be overemphasized. Car designers can profitably keep flange heights in mind when they decide to triple oversize-tires on low-flange rims. The increase in costs for the next size of rim with higher flange is insignificant compared with the penalty the car owner pays in reduced tire-service.

From the appearance viewpoint it must be admitted that, for at least the first year in service of most of our American cars, "looks" is of equal or even greater importance than performance. The increased radial depth of the drop-center-rim wire-wheel over that of the flat-base type of wire wheel, together with the less ugly blending of the spokes with the rim, makes for considerably improved wheel and car appearance. The well in the rim helps accomplish the same object as the giant hub-cap; namely, to cut down the amount of visible spoke-length.

Most car engineers believe that the drop-center rim is a better balanced and a truer-running rim than is the split or detachable-flange rim. It does away with squeaky flanges that leak water inward to the tire seat, leak rust outward to the tire side-wall, and sometimes gnaw insistently into the tire fabric.

Engineers with experience say there is no general increase in tire service when drop-center rims are used, and no general reduction in wheel weights for medium weight and heavy cars. They know there will be unfavorable complications of field service caused by the introduction of so radical a change in the method of tire attachment.

After running a number of light cars an average of over 20,000 miles under road-test conditions that covered 76 per cent high-speed driving, 20 per cent heavy sandy-road operation, 2 per cent of brake work, and 2 per cent of operation in traffic, one experimental engineer found that no tires were thrown from the rims, and no trouble was experienced that could be traceable to the method of securing the tire to the rim. The number of tires used was 26, of which 23 were worn out. The remaining three tires were punctured or cut in service.

The advantages cited for the drop-center rims in this test were: A better rim-balance, a truer-running rim, and less seepage of water. The disadvantages cited are: More effort to mount and remove tires and an out-of-balance condition of the tire on the rim due either to poor mounting or high bead-tolerance. Reassembling these tires on the rim appeared to change the point of out-of-balance.

Another experimental engineer of a high-class, heavy-type car lists these objections: Difficulty of mounting six-ply tires with side walls and beads that must be stiff and heavy enough to hold the tire during its lifetime. Mounting troubles increase as rim diameters become smaller; that is, the 18-in. tire mounts with greater difficulty than does the 19-in. size, and the 17-in. size is considerably harder to mount than is the 18-in. tire. Destruction of tubes due to valve stems pulling out when tires go flat, as well as severe cutting and tearing of tubes by the beads during car deceleration of a flat tire, were noted. There was no increase in tire service. One tire was thrown from a shallow-base rim at a speed of 15 m.p.h.; whereas, no tires came off the deeper-base rim.

A third development-engineer writes that he tried to throw the tire from the rim by firing bullets into the tires while driving at high speed. This effort to throw tires was unsuccessful.

Success Hinges on Two Main Factors

Aside from appearance, cost, ease of rolling the rim, and other commercial aspects, two factors will decide for the car owner whether drop-center rims and tires are in general better than flat-base rims and tires. One of these factors is whether an improvement over the flat-base rim has been accomplished in applying and dismounting tires to the drop-center rim. The other factor is the service and the safety of the drop-center tire itself.

The first factor, that of ease of mounting and dismounting, is controlled by a number of important interdependent elements: Depth of the well as compared with the flange height; the width of the well at the top; the width of the well at the bottom as controlled by the slope of the sides of the well; the construction, shape, flexibility, and diameter of the tire bead; the amount of air in the tube; and, finally, the methods employed, or knack of putting on and taking off the tires.

With properly designed tires and properly proportioned rims, we believe that ease of mounting favors the drop-center rim over the flat-base type of rim. Dismounting tires from drop-center rims, while a more difficult operation than mounting, can be accomplished with the same or perhaps greater ease than from flat-base rims.

The second factor, that of tire service, is closely related to tire application and removal. Until the knack of mounting and dismounting is acquired by the car owner and the field service-man, attempts to force inextensible beads over the rim flanges without taking full or partial advantage of the well will be made and will result in bead abuse even to the extent of breaking the bead wires or of weakening the beads by loosening the wires from the surrounding rubber. The extent of such tire abuse depends on the many factors already enumerated.

A second influence affecting tire service is the proper design of the inner tube. The tube must have the correct length and cross-section to blow down into the well of the drop-center rims easily and without wrinkles, and at the same time fit the corresponding flat-base rim on which the tire may be applied, both as original equipment and for field replacement. In the past the public has been accustomed, with good results, to using tubes of rather widely different dimensions on flat-base rims. Tubes for drop-center rims must be carefully designed and plainly marked for the size of casing for which they are intended.

A third tire-constituent is the design of the bead. As with the tubes, the bead must be constructed to mount on both drop-center and flat-base rims, but it must be so specially designed and shaped as to hug the rim ledge

snugly to reduce rocking, and to make such a satisfactory contact with the tube at the bead toe as to eliminate tube failure by chafing. Any old tube or casing will not give the public satisfactory results on the drop-center rim. Tire makers have spent and are still spending large amounts for equipment changes required by the swing of the industry to the drop-center rim to make tires and tubes perform in a satisfactory manner on both types of rim.

Safety Factor Considered

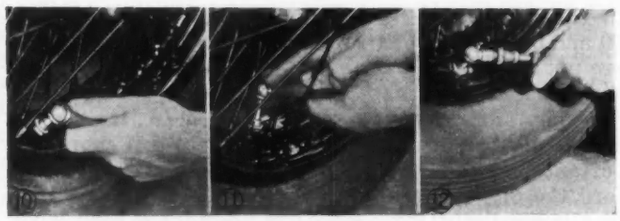
A fourth element that will influence the public greatly for or against the drop-center rim is the safety factor, as related to what happens to the tire and the car when a tire goes flat.

In all countries where the drop-center rim has gone into use, cries of lack of safety have been raised. The utterers of such cries have in some cases been those without adequate knowledge of the facts, in other cases those who were not ready to adopt the rim and who perhaps thought first of industrial or national protection of their product and second of the actual advantages and disadvantages of the rim itself as a tire carrier. Therefore, to achieve what such skeptics advanced as desirable for a safe drop-center rim, a number of rim-and-tube modifications have been marketed. Some of these modifications are ingenious but impractical and others are reasonably practical, but each has in general an outstanding drawback which militates against its acceptance as a world-wide substitute for the now generally recognized full drop-center type of rim.

In addition to such safety rims, many suggestions have been offered for modifying the inner tube to prevent the bead from getting into the well when the casing is run deflated. No one of these modifications has been practical enough as yet to warrant international adoption.

In England and America, those who have had widest experience with the drop-center rim are generally unanimous in their statements that there is no more risk in using the drop-center rim than in using the flat-base rim, from the viewpoint of deflated tires coming off and wrecking the car. English racing-cars have used drop-center rims without rim fillers. It is true that racing cars designed to make world's speed-records for short distances have fitted a band between the beads, but this was to prevent them from being drawn together by centrifugal force. From the viewpoint of the drop-center rim itself, with no detachable flanges or side rings, it is a truer, better-balanced, and perhaps stronger rim on which to run a flat tire than is the detachable-flange type of rim.

The present major drop-center rim tire-problem is not a safety problem because it is not a high-speed problem. It is a decided exception to have deflated tires throw off of drop-center rims at high speed. It is likewise a decided exception to throw deflated tires from flat-base rims at high speed. Experience records the occurrence of both incidents. At low speeds, deflated tires have been rolled off of drop-center rims by turning sharply. This does not happen frequently. A check of test-car records of one company covering over 500,000 car-miles of road service on drop-center rims discloses that not a single tire was thrown from the wheel at any speed. More than 5,000,000 American cars have been made with drop-center rims, and the consensus of opinion is that there is no serious problem of tire throwing from these rims even with the deeper well-depths used in past production.



VALVES IN ENGLISH AND AMERICAN-BUILT WHEELS

Fig. 10 Shows a Side Valve in an English-Built Wheel. English and Continental Practice Is To Bring Out the Valve Stem Through the Side Instead of Through the Center of the Well. The Picture Shows a Small-Spoke English-Built Wheel Having a Side-Projecting Valve and Resulting Inflation Accessibility

Fig. 11 Illustrates a Vertical Valve in an English-Built Wheel. The Projection of a Valve Stem Vertically Makes Inflation Difficult, Particularly on Small Wire-Types of Wheel

Fig. 12 Is a View of a Side Valve in an 18-In. American-Built Wheel. Decreasing Wheel-Diameters May Compel the Adoption of Laterally Projecting Valve Stems for American Drop-Center Rims. The Picture Shows the Accessibility for Inflation of an 18-In.-Diameter Drop-Center Large-Spoke American Wire-Wheel

Tire-Tube Difficulties Stated

A major problem is what happens to the tube. We know that tubes are occasionally ruined when run in deflated casings on flat-base rims. We might expect an increased tendency to damage tubes by running them deflated on drop-center rims. We believe a somewhat increased tendency does exist in drop-center service particularly at low speeds. At all speeds the deflated or very much under-inflated casing creeps on any rim. It creeps faster at low speeds, the tube being inclined to follow it; but the tube cannot creep if the valve is locked to the rim. If the valve holds to the rim it may pull away from the tube, after which the tube is likely to creep with the casing. If the valve holds in the tube and in the rim, the tube may be torn in two before the car can be stopped.

Unnecessary running on flat tires that are mounted on drop-center rims is greatly to be avoided. The car should be stopped as soon as possible. It is far better to remove the tire and to run on the rim. A well-talced tube is another aid to tube preservation, since it allows the creeping casing to slip on the tube. Casing creepage and resulting damage to the tube is still a major drop-center-tire problem that has not been solved, but casing creepage is not considered a hazard from the viewpoint of safety to the car occupants.

Where Do We Go from Here?

A highly accelerated trend is under way to a larger use of the drop-center-rim wire-wheel. Some car engineers are feverishly testing equipment, while others are changing over without giving much attention to testing. Wheel and rim makers are rushing in new stocks and production machinery. Tire engineers are balancing changes of stiff against flexible constructions, wide against narrow beads, long against short toes, for tires for next year's four million new-car requirements. At the same time they are trying to make this same product satisfactory for their share of replacement business on the 23 million cars running in the field.

Some people in the industries view with alarm this sudden change. We fear that terrors lurk in all changes.

(*Concluded on p. 377*)

Fuel Injection *with* Spark Ignition *in an* Otto-Cycle Engine

Annual Meeting Paper

By C. F. Taylor[1], E. S. Taylor[2] and G. L. Williams[3]

THIS investigation was carried out in the aeronautical-engine laboratory at the Massachusetts Institute of Technology to determine the practical value of the use of a fuel-injection system in place of a carbureter on an Otto-cycle engine using spark ignition. Gasoline was used for most of the investigation, but comparative tests were also made using fuel oil. The equipment used was a single-cylinder laboratory-test engine and such other apparatus as was necessary for a complete performance test. A Diesel-engine injection-pump was used. A Diesel-type injection valve was used for injection into the inlet manifold, and a valve of special design, giving fine spray and little penetration, was used for the tests in which the injection was into the cylinder.

A series of tests was run to compare the performance of an engine having (*a*) injection of fuel into the inlet pipe and (*b*) injection into the cylinder, on the one hand, with the performance obtainable with the conventional carbureter, on the other. The results of this investigation are herein presented by means of graphs of engine performance as determined from the tests and a discussion of the graphs pointing out significant facts indicated and suggesting an explanation of each.

Fuel injection, either into the inlet pipe or into the cylinder, was found to be superior in performance to the usual type of carburetion. The available power was increased by over 10 per cent with injection into the cylinder, and substantially lower fuel consumption was obtained. The mechanical problems of injection were found simpler than those of a similar system for Diesel engines. Operation with fuel oil compared very favorably with gasoline operation at a compression ratio at which no detonation occurred with either fuel. Unfortunately, this compression ratio had to be quite low on account of the poor antiknock-characteristics of the fuel oil. The influence of injection instead of carburetion of the fuel, either gasoline or fuel oil, upon the highest useful compression-ratio was insignificant.

Discussion of the paper brought out a number of suggested directions in which further research might be profitable. Among them were stratification of the charge, to produce a good mixture at the spark-plug while the total mixture-ratio is poor, and injection after the inlet valve is closed.

Reduction of the volume that must pass the inlet valve when fuel is injected into the cylinder was advanced as a reason for the greater volumetric efficiency with such injection. Vaporization of gasoline injected into the cylinder was said to be almost instantaneous, because of the high temperature that it encounters. Metering and distribution with pumps were said to be more accurate than with a carbureter at low throttle.

APPARATUS used for this investigation included a single-cylinder 5 x 7-in. N.A.C.A. universal test engine[4] together with an electric cradle-type dynamometer and the other equipment necessary for a complete performance test of the engine. The air-flow was measured by means of a sharp-edged orifice, a 50-gal. drum being interposed between the orifice meter and the engine to reduce pulsations. The fuel flow was computed from the time required to use the known volume contained in the fuel meter. A photograph of the set-up is reproduced in Fig. 1. In most of the injection tests, the carbureter was replaced by a section of plain tubing with a butterfly valve. It will be observed in the photograph that there is a 135-deg. bend in the inlet pipe near the cylinder. Fittings were attached at this point so that fuel could be injected either up or down the axis of the inlet pipe.

Fig. 2 shows the construction of the cylinder-head. Attention is called to the location of the three spark-plug holes. It will be observed that the construction of the cylinder is not favorable to setting up turbulence.

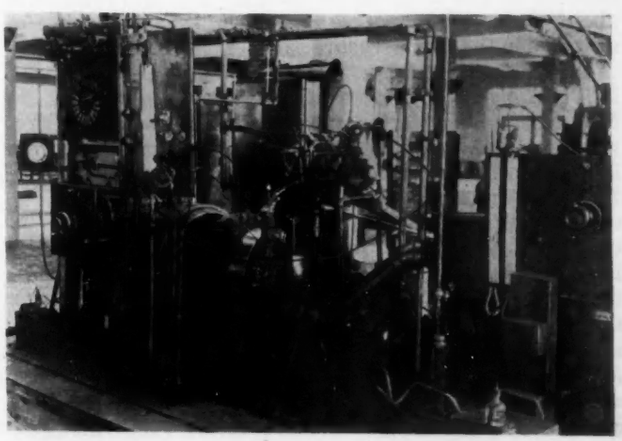


FIG. 1—UNIVERSAL N.A.C.A. TEST ENGINE SET UP FOR FUEL-INJECTION TESTS

A Bosch cam-operated plunger-type fuel-pump was used for injection, driven from a camshaft of the engine, as may be seen in Fig. 3, through a gear coupling which permits adjustment of the injection timing at will. The duration of injection for this investigation varied from 19 to 25 deg. of crankshaft rotation, ac-

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[4] See National Advisory Committee for Aeronautics Report No. 250.

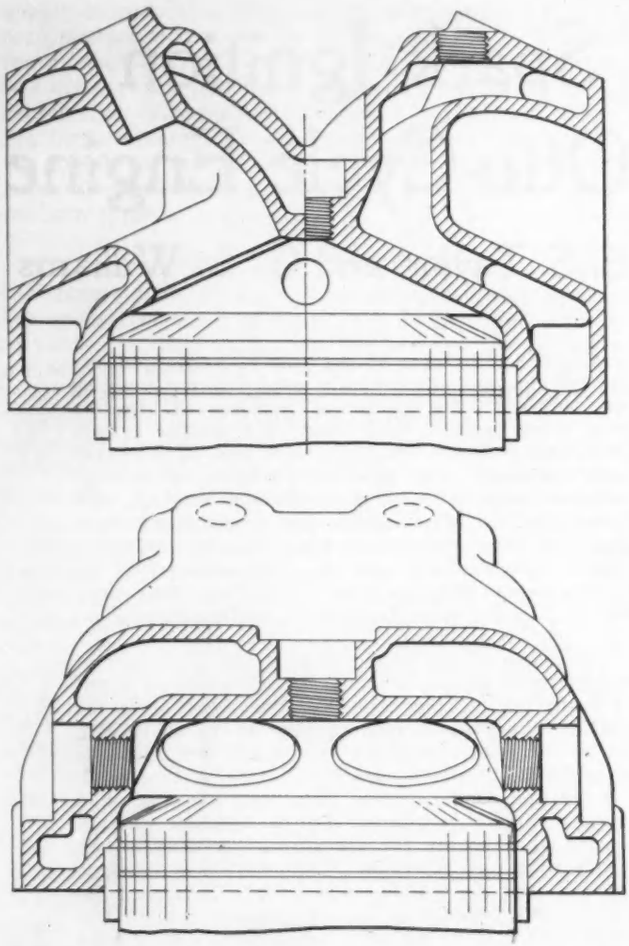


FIG. 2—COMBUSTION-CHAMBER OF N.A.C.A. UNIVERSAL TEST ENGINE

cording to the desired mixture ratio. A pressure of about 6 in. of mercury was maintained in the fuel system on the low-pressure side of the pump.

The injection valve used for cylinder injection, shown in Figs. 4 and 5, is of a type developed especially for the purposes of this investigation. With high injection-pressure, it has a high degree of atomization but very low penetration. The valve is spring loaded so that a fuel pressure of about 3000 lb. per sq. in. is required to open it. The fuel, passing out with high velocity between the valve and its seat, impinges almost perpendicularly upon the face of the hollow cone shown clearly in the enlarged section of Fig. 5, which serves to atomize the fuel very thoroughly and at the same time to absorb a large portion of the velocity of the fuel particles. The resultant spray has the shape of a wide, short cone with an apex angle of about 100 deg. and is nearly solid except for a small hollow near the apex. This valve was used in the top spark-plug hole for all tests of injection into the cylinder. At the time of this writing, this injection valve has been used for approximately 40 hr. under the various conditions of test work without trouble, either mechanical or from carbon deposit. A Bosch injection valve with a pin-type spray nozzle giving a 30-deg. conical spray was used for injection into the inlet pipe.

All tests were made at full throttle with the load adjusted to maintain a constant speed of 1500 r.p.m. Compression ratios from 3.5: 1 to 5: 1 were used for these tests. Most of the tests were made with a compression ratio of 4.3: 1 and a constant spark-advance of 28 deg. The mixture ratio was varied for each injection arrangement from the lean limit to very rich, and observations were taken during each run to determine the brake horsepower, fuel consumption and air consumption.

Injection into Inlet Pipe

Tests were made first with the conventional carbureter, to afford a basis of comparison. Then the injection valve was placed in position in the inlet pipe to inject the spray in the same direction as the incoming air, for the first set of runs. For the next group of runs, injection was down the pipe against the air-flow. The Bosch valve was used for these runs, and the carbureter was left in place with its fuel jets closed. The fuel was injected into the inlet pipe during the suction stroke, beginning 30 deg. after top center, and continuing for about 21 deg. of crankshaft rotation.

Performance curves from these tests are shown in Fig. 6. There is seen to be little difference between the power obtained with the carbureter and that obtained with injection. Injection against the air-flow seems to be slightly better than injection in the same direction as the air-flow.

The outstanding indication of these curves is the fact that nearly full power is maintained with inlet-pipe injection to a leaner limit than can be obtained with the carbureter. Also, the minimum specific fuel consumption with inlet-pipe injection is considerably lower than that with the carbureter.

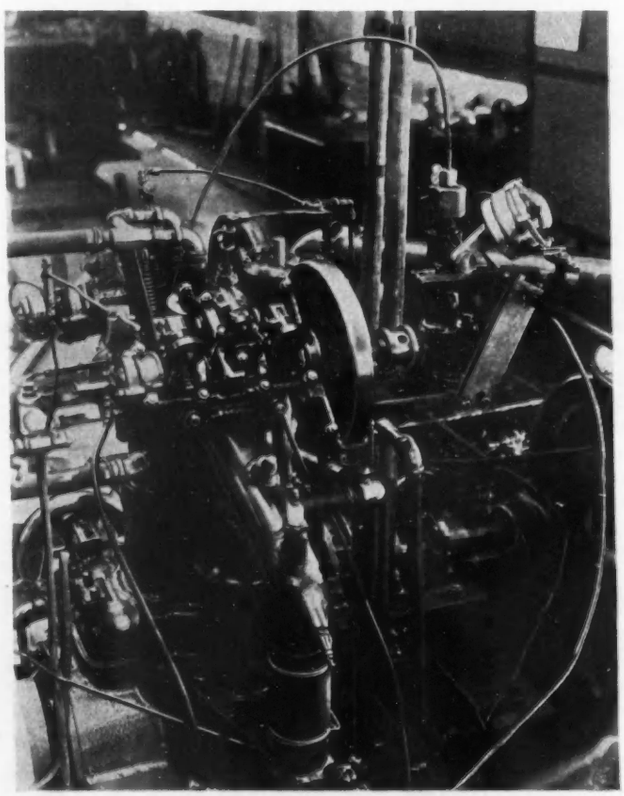


FIG. 3—TOP OF UNIVERSAL TEST ENGINE
Injection Pump Is Shown at the Right, Coupled to a Camshaft

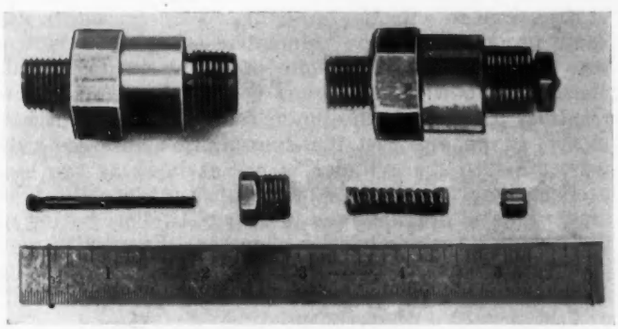


FIG. 4—FUEL-INJECTION VALVE AND DETAILS

With injection of the fuel it is probable that more nearly the same amount of fuel gets into the cylinder for each explosion than with the carbureter. When the mixture ratio for successive explosions is not uniform, the effect on performance is exactly the same as the effect of unequal distribution of fuel between cylinders in a multi-cylinder engine. The effects of uneven distribution have been calculated arithmetically by S. W. Sparrow[5]. He shows that poor distribution, in comparison with good, results in (*a*) the points of maximum power and minimum fuel-consumption occurring at richer mixtures and (*b*) a general flattening of the curves of mean effective pressure and fuel consumption versus mixture ratio. Both of these effects are observable in the curves of carbureter performance as compared with the curves with injection.

The tests discussed in the foregoing were repeated with the carbureter removed and replaced by a section of plain tubing. The performance curves from these tests are shown in Fig. 7, in which the curves obtained with the carbureter functioning are plotted for comparison.

The principal effect of removal of the carbureter is a large increase in volumetric efficiency with a corresponding increase in brake mean effective pressure. This gain in performance may be considered as a direct advantage of the manifold injection.

The comparatively sharp break in performance at the lean limit is again clearly illustrated. Injection down the inlet pipe is consistently better than injection in the direction of the air-flow. The gain in maximum brake horsepower with injection into the inlet pipe is 6.5 per cent. The corresponding gain in volumetric efficiency is 6.65 per cent. This gain in volumetric efficiency seems to be due entirely to the removal of the carbureter.

Injection into the Cylinder

Fuel injection into the cylinder was through the top spark-plug hole. The beginning of injection was varied from 30 to 120 deg. after top center during the suction stroke. Injection timings later than these were found to involve difficulties common to Diesel engines; namely, incomplete distribution of the fuel through the combustion-chamber and incomplete vaporization, which difficulties were augmented by the fact that the comparatively low temperature at the end of compression in the Otto cycle imposes limits on the range of combustible mixtures which are not present under the high-temperature conditions of the Diesel cycle. Furthermore, it is of course necessary to have a combustible mixture between the sparking points. The duration of injection was about 21 deg. of crankshaft rotation.

Since the fuel was injected during the suction stroke, the pressure in the cylinder was in general about atmospheric. Therefore, inspection of the spray into the air outside the cylinder gave an excellent indication of the spray characteristics in the cylinder. It is obvious that an injection valve with a penetration of several feet in the open air would, when placed in the cylinder, spray most of the liquid fuel onto the opposite side of the combustion-chamber. This was found to be the case when such an injection valve was tried; the engine backfired and missed and had scarcely enough power to overcome engine friction.

The new type of injection valve was developed to have good atomization but very low penetration. An inspection of the spray from this valve in the open air showed it to have the shape of a cone having an apex angle of about 100 deg. and a maximum penetration of less than 1 ft. The construction of the valve is described at the beginning of this paper.

The effect of injection timing is shown in Fig. 8. For each timing, points corresponding to the performance at a mixture ratio which gave 98 per cent of the best power are plotted. As was to be expected, early injection gives the best performance in every respect, since more time is allowed for thorough distribution of the fuel through the combustion space and for vaporization. However, there seems to be little gain from injecting

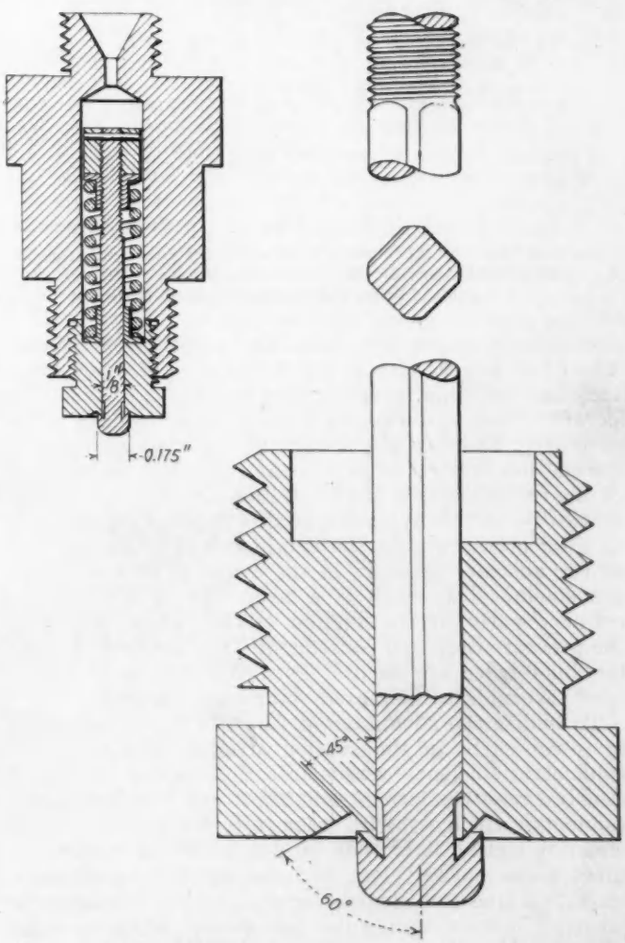


FIG. 5—INJECTION-VALVE ASSEMBLY AND ENLARGED DETAILS

[5] See National Advisory Committee for Aeronautics Technical Note No. 162.

much earlier than 45 deg. after top dead-center. Thirty degrees after top center was adopted as a standard injection-timing for these tests.

Performance curves obtained from the tests with 30-deg. injection-timing are shown in Fig. 9, together with the performance curves previously shown, obtained with the carbureter and with injection down the inlet pipe with carbureter removed, for comparison.

The outstanding indication of these curves is the consistent increase in volumetric efficiency with injection into the cylinder. This effect can be fully accounted for by consideration of the decrease in sensible heat content and the corresponding decrease of temperature and pressure of the gases in the cylinder which results from injection of the fuel. It should be remembered that, early in the suction stroke, the cylinder contains mostly

Brake mean effective pressure is increased in the same proportion as the volumetric efficiency except at lean mixtures where, in spite of better volumetric-efficiency, the power falls below that with injection into the inlet pipe. Since minimum fuel-consumption occurs in this range, the best fuel-consumption obtained with injection into the cylinder is not as good as the best fuel-consumption obtained with injection into the inlet pipe. This is probably due to imperfect distribution of fuel through the combustion-chamber. Even with very low penetration of the spray there is a tendency to project the fuel at least some distance, so that it might well be expected that the mixture of fuel and air in that part of the combustion-chamber near the injection valve would be somewhat leaner than the mixture on the opposite end of the combustion space. Since the

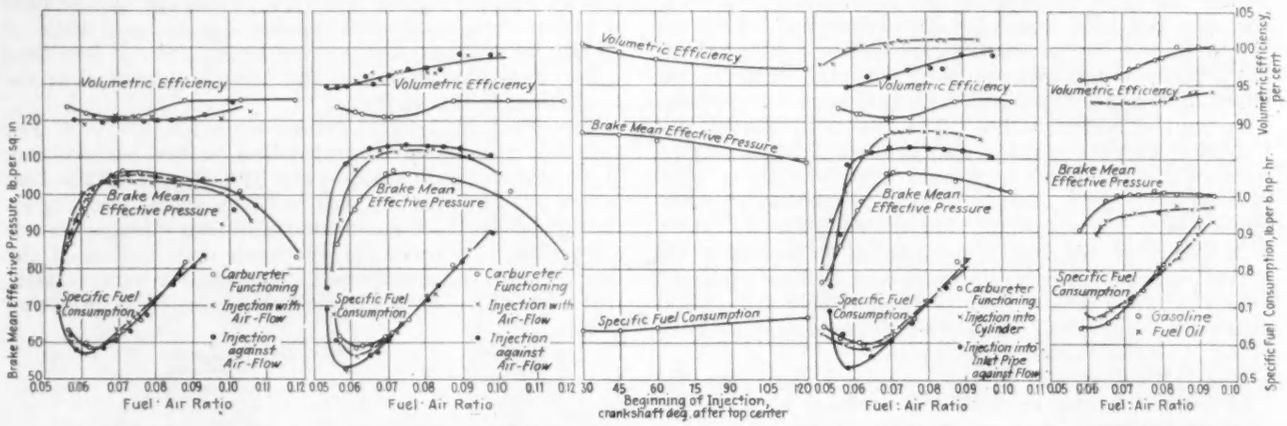


Fig. 6—Runs with Carbureter in Place

Fig. 7—Runs with Carbureter Removed. Reference Curves with Carbureter Functioning

Fig. 8—Effect of Timing of the Injection into the Cylinder

Fig. 9—Curves from Injection into Cylinder, Injection into Inlet Pipe against Air-Flow and Operation with Carbureter

Fig. 10—Curves from Injection of Fuel Oil, with Gasoline Reference Curve. Spark-Advance, 30 Deg.

CURVES FROM FUEL-INJECTION TESTS

Data Applicable to All Curves Except Where Otherwise Specified Are as Follows: Engine Speed, 1500 R.P.M.; Compression Ratio, 4.3:1; Spark-Advance, 28 Deg. Injection Begins in Suction Stroke 30 Deg. after Top Center. Fuel, Domestic Aviation Gasoline. All Data Reduced to Basis of 30-In. Barometer and 70 Deg. Fahr. Atmospheric Temperature

hot exhaust gases left from the preceding explosion. The effect of injection of the full charge of finely atomized fuel into this inert but very hot gas is a large temperature drop and a corresponding pressure drop in the cylinder. The partial pressure of the gasoline vapor at normal mixture-ratios is less than the drop in pressure of the residual gases due to cooling. It is shown mathematically, in the Appendix of this paper, that the drop in total pressure is in the neighborhood of 16 per cent of the absolute pressure in the cylinder, or about 2 lb. per sq. in. The result is a large flow of air into the cylinder early in the suction stroke, when ordinarily the pressure drop and consequently the air-flow through the inlet valve are small. This condition is obviously very favorable to increased volumetric-efficiency.

To realize the advantage of this effect it is necessary to inject early in the suction stroke. The graph of volumetric efficiency versus injection timing in Fig. 8 clearly shows the loss of this effect and the diminished volumetric efficiency with later injection timing. With injection timing later than 90 deg. after top center the effect seems entirely lost, and the volumetric efficiency becomes a constant almost identical with the volumetric efficiency corresponding to best-power mixture with inlet-pipe injection.

spark-plugs are, like the injection valve, located in the upper part of the cylinder, they also are in the region where the mixture may be leaner than the average mixture in the cylinder. Therefore, when the average mixture-ratio in the cylinder approaches the lean limit, the actual mixture near the spark-plugs may be so lean as to be outside the range of good combustion, and a considerable loss of power may result.

If this analysis is correct, good turbulence in the cylinder should go a long way toward remedying the trouble. It is hoped that these tests may be partially repeated in the near future with some means to establish at least a fair degree of turbulence. Even under present conditions, injection into the cylinder is in performance superior to carbureter operation. It is possible that, with good turbulence, cylinder injection will give as good specific fuel-consumption at the best-economy mixture as does injection into the inlet pipe.

Tests were made to determine the knocking characteristics of the engine with fuel injection into the cylinder by raising the compression ratio to the point of incipient detonation. The engine was throttled to give the same volumetric efficiency with fuel injection as with the carbureter. Apparently it made little difference to the knocking characteristics whether the fuel

was introduced through the carbureter or through the injection valve.

Fuel-Oil Injection

No change in set-up was made for fuel-oil injection except to lower the compression ratio to 3.5:1, which was the highest useful compression ratio for the fuel oil, to avoid detonation. Attempts to operate the engine with fuel oil injected into the inlet pipe were failures, and no tests were made with this injection arrangement. With injection into the cylinder, the operation of the engine on fuel oil was very similar to its operation on gasoline. The performance obtained at such a low compression-ratio cannot be compared with the performance obtained with gasoline at higher compression-ratios in the tests already discussed. Fig. 10 shows the performance obtained with fuel oil and, for comparison, the performance obtained with gasoline at the same compression ratio.

The decrease in volumetric efficiency with use of fuel oil is very marked. This can probably be explained by the consideration that fuel oil, because of its low rate of vaporization as compared with gasoline, corresponds to a late injection of gasoline, in which case the cooling effect of vaporization of the fuel upon the cylinder gases occurs too late to be of much benefit to the volumetric efficiency. This decrease in volumetric efficiency is accompanied by a proportional decrease in brake mean effective pressure. The increase in specific fuel consumption is probably due to poorer vaporization. The fuel consumption with fuel oil becomes less than that with gasoline at mixtures richer than the best-power mixture. This may be explained by the fact that fuel oil contains some heavy ends that do not vaporize, so that the effective mixture-ratio is somewhat leaner than the apparent one. It may be observed that—for the same reason, apparently—the best-power mixture with fuel oil is considerably richer than the best-power mixture with gasoline.

It was found in this investigation that, with late injection of gasoline and especially with fuel-oil injection, there is a distinct advantage in using automobile-type spark-plugs having well-exposed points rather than the aeronautic type having the gap within the body of the plug. This circumstance is probably due not so much to higher temperature of the exposed spark-plug points as to the better mixture at the spark gap.

It was found possible to start the engine on fuel oil without previous warming up, but considerable trouble was experienced from fouling of the plugs during the warming-up process.

Throttling

All of the tests herein described were run at wide-open throttle, except when a slightly closed throttle was used to reduce the volumetric efficiency with injection to that obtained with the carbureter. In any practical application of fuel injection, it would be necessary to regulate the air throttle and the fuel-quantity control over the useful speed-load range so that the desired mixture ratio would be obtained. This could be accomplished by a simple mechanical interconnection between the air throttle and the fuel-pump control in the case of airplane or marine installations, in which the speed-load relation is fixed, approximately, along a single curve, but it would be much more difficult in the case of road or rail applications in which there is no such definite relation between speed and load. For such applications, several possible methods of control would be available, among which may be mentioned the following: (*a*) a modification of the relation between throttle position and fuel-pump control, operated by the manifold vacuum or by a speed-controlled governor; (*b*) simultaneous hand control of the fuel-pump and of a manifold-depression regulating-valve; (*c*) manual control of either the fuel-pump or the throttle, with manifold-vacuum or governor control of the other element; and (*d*) simultaneous control of air-throttling and fuel-throttling valves.

Conclusions

As a brief summary of the results of this investigation the following conclusions are suggested:

(1) High-pressure fuel-injection either into the inlet pipe or into the cylinder is superior to carburetion in respect to performance. The maximum available power may be increased by 7 to 11 per cent, depending on the method of injection. This increase in power is due partly to the elimination of the pressure drop through the carbureter and partly to direct effects of the spray itself. The improvement in specific fuel consumption may be traced to more even distribution of the fuel between successive cycles, and to a lesser extent to the higher mechanical efficiency which accompanies the gain in power.

(2) The highest useful compression ratios, as fixed by detonation characteristics, are essentially the same with injection of the fuel as with carburetion, at the same volumetric-efficiency.

(3) The best power is obtained with injection of the fuel into the cylinder, and the best fuel-consumption is obtained with injection into the inlet pipe against the air stream. It is expected that good turbulence would improve the fuel consumption with injection into the cylinder.

(4) Fuel oil can be used as well as gasoline for injection into the cylinder except for the more severe limitations upon useful compression-ratio fixed by its detonation characteristics and its tendency to foul the plugs during the warming-up process.

While it is beyond the purpose of this work to investigate thoroughly the mechanical aspect of fuel injection, it may be said that the problems and requirements of the injection system are very similar to those encountered in the corresponding Diesel-engine parts, but they are much simplified by the relative unimportance of exact injection-timing and of very accurate rates of injection. Certainly, in view of the fact that Diesel systems have already been built to give very satisfactory service, no particular trouble should be experienced along this line. However, with gasoline injection it is important that lubrication be provided for the pump plunger and that close fits be avoided at sliding surfaces in the injection valve. Otherwise binding and wear will result, with ultimate failure of the parts.

APPENDIX

Calculation of Pressure Drop

The theoretical drop in total pressure in the engine cylinder due to the cooling effect of the injected gasoline may be shown by the following consideration of the change in sensible heat-content and the correspond-

ing change in pressure of the cylinder contents at the time of injection.

For the purposes of computation, it is necessary to establish the following conditions and to make the following assumptions:

(1) Compression ratio, 4.3:1
(2) Fuel: air ratio, 1:14
(3) Injection occurring during the suction stroke at 30 deg. after top center
(4) Clearance-space volume equal to one mol[6]
(5) Temperature of residual exhaust gases, 1000 deg. fahr.
(6) Temperature of air intake, 70 deg. fahr.

The total volume in the cylinder at the beginning of injection is the clearance space plus the volume displaced by the piston during the first 30 deg. after top center:

$$1.00 + 0.33 = 1.33 \text{ mols}$$

The approximate composition of the cylinder contents, in mols, at the beginning of injection is

Element	Exhaust Gas	Air	Total
N_2	0.843	0.284	1.127
CO_2	0.109	...	0.109
CO	0.036	...	0.036
O_2	0.012	0.046	0.058
Total	1.000	0.330	1.330

Since the specific heat of the exhaust gases is approximately the same as that of air, the resultant temperature of the gases in the cylinder, in degrees fahrenheit, may be found as follows:

$$1000 - (1000 - 70) \cdot (0.33 \div 1.33) = 770$$

The latent heat of vaporization of gasoline is taken as 90 B.t.u. per lb. and its specific heat as 0.5. The molecular weight of gasoline is about 120 and that of air is 29.

Since the compression ratio is 4.3:1 and the clearance volume is equal to 1 mol, the piston displacement must be 3.3 mols and the weight of air drawn in, assuming 100 per cent volumetric efficiency, will be approximately, in pounds

$$3.3 \times 29 = 96$$

and the weight of fuel injected, in pounds

$$96 \times 1/14 = 6.83$$

The corresponding volume of gasoline vapor, in mols, is

$$6.83 / 120 = 0.057$$

The total heat absorbed by the gasoline upon injection into the cylinder is the sum of the heat of vaporization and the heat required to raise the temperature of the vapor to the resultant temperature in the cylinder after injection.

Coefficients of decrease in sensible heat in British thermal units per mol per degree fahrenheit for the various gases in the cylinder can be determined from curves of sensible heat content versus temperature.[7]

Letting b represent the temperature drop in the cylinder due to injection, we may set up the following equation and solve for b

$$b \times 1.127 \times 7.4 + 0.109b \times 12 + 0.036b \times 7.4 + 0.058b \times 7.4 = 6.83 \times 90 + 6.83\ (770 - b - 70)$$

where 7.4 and 12 are sensible-heat coefficients of the various gases.

Solving for b,

$$b = 220 \text{ deg. fahr.}$$

The resultant temperature in the cylinder is then

$$770 - 220 = 550 \text{ deg. or } 1010 \text{ deg. fahr. abs.}$$

The total number of mols in the cylinder after the injection of 0.057 mols of gasoline is

$$1.33 + 0.057 = 1.39$$

New pressure = original pressure $\times$ 1010/1230 $\times$ 1.39/1.33 = 0.858 $\times$ original pressure.

If the original absolute pressure was atmospheric, or 15 lb. per sq. in., the new pressure must be 15 $\times$ 0.858 = 12.9 lb. per sq. in.

The pressure drop = 15 — 12.9 = 2.1 lb. per sq. in.

THE DISCUSSION

M. A. MIERAS[8]:—To obtain a correct mixture-ratio in a conventional engine with a fuel-pump under the conditions of these tests is comparatively easy, but it would be quite a problem to do the same for a range of engine speeds from, say, 300 to 2000 r.p.m., such as is common in the present aviation engines. It would probably be possible to improve very much the volumetric efficiency of an engine having a carbureter by using a larger carbureter if it were to be run only at a constant speed of 1500 r.p.m.

Gasoline flowing along the manifold walls probably is a problem at low engine-speeds but not much of a problem at speeds equivalent to cruising and full-throttle speeds in an airplane engine.

The fuel-air ratio at airplane cruising speeds probably is about 0.08. The curves in Figs. 6, 7, 9 and 10 show little variation in specific fuel consumption at that point. The present trend toward rotary induction systems makes it possible to obtain much higher volumetric efficiency at high speeds while still using a carbureter having a small choke to give sufficient air-speed in the manifold for good distribution at low engine-speed.

J. L. GOLDTHWAITE[9]:—The development of a nozzle which gives a fine spray without penetration is one of the greatest contributions brought out in this paper.

Refrigeration from vaporization of the gasoline was suggested by the authors as the cause of the high volumetric efficiency secured with direct injection into the cylinder, but the refrigeration is the same whether the gasoline is sprayed into the manifold or into the cylinder. Another factor which might enter is the volume of gas resulting from the vaporization of gasoline, amounting to perhaps 3 per cent, which, in the case of manifold injection, increases the volume that must pass through the inlet valves.

Two or three other items might bear further investigation. One is that a point may be reached when working with very high mean effective pressures, as with supercharging, at which the cylinder-walls would be drenched unless the air is preheated. Therefore we should know how much preheating of the air is neces-

[6] Regarding the use of mol as a measure of volume, see Principles of Thermodynamics, by G. A. Goodenough, third edition, p. 269. Henry Holt & Co., New York City.

[7] See Principles of Chemical Engineering; by William Hultz Walker, W. K. Lewis and William Henry McAdams, published by McGraw-Hill Book Co., second edition, 1927.

[8] Jun. S.A.E.—Engineer, Detroit Aircraft Corp., Detroit.

[9] Allison Engineering Co., Indianapolis.

sary both with carburetion and with direct injection. Presumably more would be required with the carbureter; but it would be valuable to know, because that would affect the maximum power that could be obtained with supercharging.

Another subject for investigation is the speed at which the power peak occurs. I suppose that the peak is at a higher speed with the carbureter restriction eliminated, and it would be valuable to know how much the speed can be raised without loss of power.

Weak Mixtures Burned with Stratification

Hope exists in regard to low-throttle operation and idling. Proportioning air and fuel for idling with an injection nozzle may seem almost hopeless, but I have heard of several researches in which fuel was injected into the cylinder and the stratification was such that a very weak mixture could be burned because the mixture around the spark-plug was good.

G. L. WILLIAMS:—The combination of increased density with the reduction of 2 per cent in the volume that must pass through the inlet valve, together with the increased pressure-drop through the inlet port due to injection of the fuel, evidently gives better volumetric efficiency with injection into the cylinder than can be obtained when only the benefit of the increase in density is available. With the carbureter, gasoline is introduced throughout the suction stroke, and some of it does not come until the end of the stroke. Gasoline injected into the cylinder at the beginning of the stroke provides benefit during the whole stroke.

L. E. FOWLER[10]:—Fuel injection has been mentioned as a good substitute for the carbureter. I believe that we shall soon recognize it as a very definite improvement over the carbureter. An engine designed for use with the injection system would have a much larger manifold than one equipped with a carbureter, which would increase its volumetric efficiency.

Did the work done indicate that the engine could be controlled by the quantity of fuel alone, as in a Diesel engine?

Mention has been made of the necessity for preheating the air. Could not the same effect be obtained by preheating the gasoline?

Was any work done in connection with pressure ignition and gasoline injection?

Injection work about which I have read indicates that the distance from the point at which the fuel is injected to the point of combustion has a considerable effect on its distribution through the air. Interesting light is given by experience in introducing oil into the steam for lubricating the cylinders of steam-engines. In this work it was found necessary to drop the oil into the steam 8 ft. away from the engine to secure complete diffusion of the oil through the steam.

Do you think, from your own investigation or from reports of other work, that fuel injection will save the power that is lost through ordinary manifold distribution from the carbureter?

Ample Heat for Vaporization

MR. WILLIAMS:—Our work was confined to spark ignition; we did nothing with compression ignition.

Concerning preheating of the fuel, consideration of the fact that it is injected 30 deg. after top center, at a time when the temperature in the cylinder is about 1000 deg. fahr., makes it seem that the fuel must be vaporized immediately. Fairly complete vaporization is secured with fuel oil, and there can be little doubt that vaporization is almost instantaneous with gasoline.

Application of the system to multicylinder engines does not seem difficult. Perhaps the best sort of injection unit would be a single pump and distributor. A system having an individual pump for each cylinder involves the problem of keeping the pumps adjusted to give the same mixture ratio for each cylinder, and the conditions will be just as bad as with a carbureter if the pumps are not correctly adjusted.

CHAIRMAN CHARLES L. LAWRANCE[11]:—This paper states that when the mixture is made too lean there comes a point at which the engine fires irregularly or not at all. It was suggested that this might be due to lack of turbulence and that better turbulence would enable the engine to run on a leaner mixture, the assumption being that the charge was not evenly distributed and a good charge did not reach the spark-plugs. There may be great possibilities in using less turbulence rather than more, locating the spark-plugs so that they are at the richest rather than the leanest part of the mixture. That might make possible running with much lower fuel consumption than can be attained at present. Of course these experimenters have had no opportunity to develop anything along that line, but it seems like a profitable direction for future study.

J. OTTO SCHERER[12]:—One of the greatest complaints about the Otto-cycle or carbureter engine is the limitation of compression on account of knock troubles. I am disappointed that this paper does not cover injection very close to the time of ignition, thus approaching the Diesel engine in which the rate of injection influences the combustion. Such a procedure would make possible high compression without danger of knocking and might provide a localized combustible mixture. I believe that such a development promises richer rewards than does merely replacing the carbureter by an injection pump and injecting the fuel before the compression stroke is begun.

C. F. TAYLOR:—We were unable to run the engine with injection immediately before ignition, since it would not fire regularly. When we have developed the method to a point where injection just previous to ignition is practicable, it will be very interesting to explore the effects of detonation.

Lines To Follow in Future Experiments

THOMAS S. KEMBLE[13]:—Any pioneering investigation such as this must fail to go into all the questions that it suggests. I consider it a real contribution.

What injection pressures were used, was the effect of variation in the pressure investigated?

MR. WILLIAMS:—We did not try variation of the pressure. The pressure we used was from 3000 to 3250 lb. per sq. in., which gave the complete atomization and low penetration which we were seeking.

C. F. TAYLOR:—We were a little reluctant to offer this paper because many others have probably been over the same work. However, we are in the fortunate position of having nothing to sell and are therefore able to publish our results openly, and we thought that the paper might be of interest to those who have not

[10] Fowler Engines, Pontiac, Mich.

[11] M.S.A.E.—President, Lawrance Engineering & Research Corp., New York City.

[12] M.S.A.E.—Consulting engineer, Detroit.

[13] M.S.A.E.—Pennington Engineering Co., Cleveland.

done work along these lines or had access to the results of similar tests in other laboratories.

What we have reported is only a preliminary attempt; all we have tried to do is to demonstrate what can be done quickly by applying a conventional fuel-injection system to a conventional type of cylinder. Some of the remarks in this discussion point the way to further interesting developments which we hope to pursue as rapidly as possible.

Mention has been made of supercharging. The injection pressure is high enough so that this system will work without modification with any probable supercharging pressure. Freedom from danger of manifold explosions is quite a desirable feature in this connection.

Fear of difficulty in metering the small quantities of fuel required in idling is apparent. Well-made metering pumps appear to be more accurate at low speeds than are carbureters and manifolds. There seems to be no difficulty at all in the mechanical metering of small quantities of fuel.

Questions of turbulence and stratification offer an interesting field for further work, as also does injection after the inlet valve is closed. The latter is of interest, particularly in connection with a two-cycle engine.

A multiple-cylinder engine with this system becomes so many individual cylinders having no interrelation which might cut down the total power of the engine, as it may when a number of cylinders are fed by a single carbureter.

One of the most promising aspects of the whole investigation is the possibility of using heavier fuels, with their corresponding reduction of fire risk. Dr. Dickinson has suggested that the hydrogenated fuels, described in Mr. Haslam's paper[14], may be very appropriate for this type of engine, on account of the excellent antiknock properties of the heavier fractions.

A Two-Cycle Fuel-Injection Aeronautic Engine

JOHN F. SANDELL[15]:—We are experimenting with a two-cycle fuel-injection aeronautic engine, scavenged and supercharged from a Roots-type blower. It is a four-cylinder inverted V-type air-cooled engine having a bore and stroke of 4¾ x 5¼ in., the piston displacement being 372 cu. in. It develops 125 hp. at 1500 r.p.m., 158 hp. at 1600 r.p.m. and 175 hp. at 1650 r.p.m. We expect to be able to run the engine at 1800 r.p.m, at which speed we anticipate about 230 hp The power has been measured by means of a calibrated four-blade test club. At 1650 r.p.m., which is the highest speed we have used so far, the useful horsepower is about ½ hp. per cu. in. The complete engine, shown in Fig. 11, weighs 380 lb., 56 lb. of which is the blower.

Inlet to the cylinders is through a valve in the head, actuated by a camshaft, push-rod and rocker-arm. The inlet valve opens about 6 deg., or ⅛ in., after the piston has uncovered the exhaust port, allowing the cylinder to be scavenged by air from the blower. The injectors spray the fuel into the passage leading to this valve, through a small tappet valve similar to that described in the paper by Messrs. Taylor, Taylor and Williams. The timing is set so that no fuel escapes through the exhaust port, as the piston closes the port before the fuel is carried down to this point by the air. The compression ratio is 4.7:1 figuring from the point at which the ¾-in.-high exhaust ports are closed.

We have operated this engine with Ethyl aviation gasoline, with ordinary aviation gasoline of 66-per-cent iso-octane rating, with ordinary gasoline, with kerosene, and with fuel oil having a specific gravity as low as 32 Baumé. It runs very successfully on the fuel oil, developing about 15 per cent less power than with gasoline at the same throttle opening. The very thorough breaking-up of the fuel spray by the high speed of the air rushing past the spray valve makes the operation of this engine possible with heavy fuels.

The supercharger, which runs at 2¼ times crankshaft speed, is capable of delivering a pressure of 12 lb. per sq. in. at ground level, but an air-relief valve regulates the pressure to 6 to 7 lb. This valve will gradually close at higher altitudes, the engine maintaining constant power.

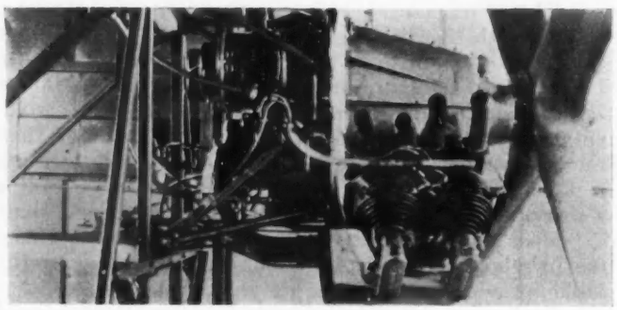


FIG. 11—SANDELL'S SUPERCHARGED TWO-CYCLE ENGINE

The engine idles successfully at 350 r.p.m. Throttling is controlled by a butterfly valve in the air passage at the cylinder-head, interconnected to the control which regulates the amount of fuel injected per stroke. When the butterfly valve is only slightly open, for low or idling speeds, the air pressure builds up behind it and causes a puff of air when the inlet valve opens, blowing out the old charge with just enough pressure to carry the new charge past the valve, resulting in a stratification. The fuel-injection pressure is 800 lb. per sq. in.

Lubrication is under pressure of 80 lb. per sq. in. through oil passages in the crankshaft. As pressure above the pistons is continuous, the pistons and rings are made to favor oil passage from the crankcase to the cylinder walls. Fuel consumption is between 0.52 and 0.53 lb. per hp-hr. The mean effective pressure at 1650 r.p.m. with wide-open throttle is 122 lb. per sq. in. The crankcase, which is made of magnesium, has breathers. The cylinder-barrels are turned from steel forgings; and the cylinder-heads are aluminum, screwed and shrunk on. Cylinder temperatures, measured just below the head, at the highest spot, vary between 340 and 380 deg. fahr. Ignition current is supplied by two Scintilla magnetos, one of which is driven through an impulse coupling to facilitate hand-starting. The engine can be started with furnace oil in the injection pumps by priming with gasoline.

C. F. TAYLOR:—The engine described by Mr. Sandell certainly seems to be an interesting development. Many of the problems which we found in our experimental work evidently have been solved in this engine. I shall await the publication of further details and dynamometer performance results with a great deal of interest.

[14] See S.A.E. JOURNAL for March, 1931, p. 307.

[15] Sandell Motors, Chicago.

A FLEET of 265 motorcoaches, mostly of the larger type, is operated by the transportation companies with which I am associated; that is, the Akron Transportation Co., the Northern Ohio Interurban Co., the Canton Traction Co., and the Penn-Ohio Coach Lines. These companies, formerly known as the Northern Ohio Power & Light Co., have been operating motorcoaches since April, 1922. Because we have bought-out many different transportation lines, we have operated practically every make of motorcoach, although, at present, by retiring some of the different makes, the fleet is now composed of only seven different makes of vehicle. The number of motorcoaches operating in the city service is 200, and the remainder operate on interurban lines from Akron to Cleveland, to Canton and other neighboring towns. As Akron is a very hilly city and the fare is low, with consequent heavy loads to meet operating expenses, the city service is very severe.

As the Northern Ohio Power & Light Co. was originally operating electric street-cars, we felt that the same methods of maintenance and repair that have been used on the steam railroads and electric railways throughout the Country could be applied with modifications to the maintenance of motorcoaches. With this idea in view, we worked out a daylight inspection-system which corresponds closely to the inspection applied to the railway cars.

In the maintenance of locomotives, the steam railroads used their roundhouses for inspection and their shops for heavy repairs; the electric railways used the inspection shop and main repair-shop. In motorcoach work we are using the inspection garages, which take care of the servicing and minor repairs, and our heavy-repair shop which is the same shop that is used for electric-car repair. Many of the men, such as carpenters, painters and machinists, work on both motorcoaches and electric cars. In this way the shop facilities have been made to do double duty with maximum economy.

After outlining the organization of the company he represents, the author discusses the factors governing layout and the procedure by which a fleet of 265 motorcoaches is maintained. Plans of the several garages are shown, and the practices with regard to the purchase and handling of gasoline and oil, as well as the scheduling of lubrication, are stated.

Conferences are held with the foremen, who receive advance reports which they are expected to study and to discuss at the succeeding conference.

A description is given of the report forms used in keeping records, the practice with regard to heavy overhauling is stated, and engine rebuilding is outlined in some detail.

Inspection-Garage Layout and Procedure

In laying out the inspection garages, the greatest amount of care was used in figuring out the movements of the motorcoaches through the garages to secure the minimum amount of lost movement and congestion. The locked magazines are removed from the money boxes as the vehicles enter, so that none of the company's money is in the motorcoaches while they are in the garage. Facilities for the rapid filling of the gasoline tanks, oiling the engines, and filling the radiators are in-

[1] M.S.A.E.—Vice-president and general manager, Akron Transportation Co., Akron, Ohio.

stalled just inside the entrance. A set of sprays for washing the motorcoaches is shown in the head piece. An arrangement for the cleaners to scrub the vehicles and a second set of sprays for rinsing them off complete the servicing arrangement. The motorcoaches are then spotted to take care of any repairs or, if no work is necessary, they are located in position for going out the following morning.

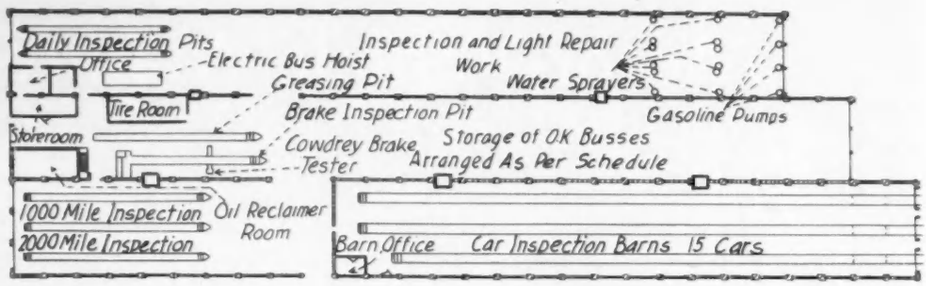


FIG. 1—ARRANGEMENT OF THE KENMORE GARAGE

Originally This Was a Three-Bay Inspection-Barn. At Present a Small Part of One Bay Is Used for Electric Cars and the Remainder of the Building Constitutes a Very Convenient Garage

None of the company's garages was originally built for this purpose; they were car barns, public garages, or other buildings. Therefore, the arrangements are not ideal, but some of the buildings have worked out nearly as well as though a new building had been designed.

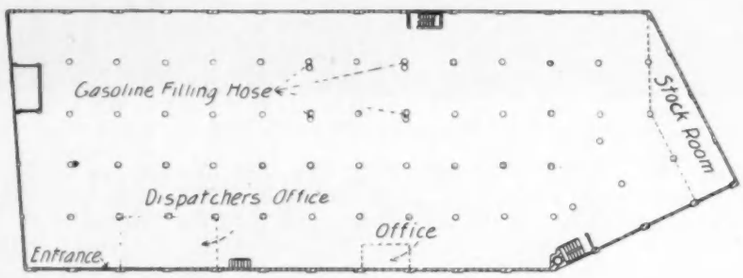


FIG. 2—PLAN OF THE CENTRAL GARAGE

This Garage Is Located on the Third Floor of a Large Storage-Garage. It Has Only One Entrance and Exit and the Columns Are Spaced 25 Ft. Apart. Hence, It Is Very Awkward To Handle Large Vehicles Therein; But They Are Handled Satisfactorily by Moving Them between Certain Lines of Columns Which Act as Passageways

Fig. 1 shows the arrangement of Kenmore garage. This was originally a three-bay inspection-barn. Now, only a small part of one bay is used for electric cars, and the remainder of the building has been made into a very convenient garage. The motorcoaches enter through the first bay and they exit through the second bay.

Fig. 2 shows the plan of Central garage, which is the third floor of a large storage-garage. It has only one entrance and exit and has a 25-ft. spacing of columns, making it very awkward to handle large motorcoaches; but they are brought in and moved through a regular course between certain lines of columns which act as passageways. Fig. 3 shows the ground plan of our East Akron garage, which was a small double-end car inspection barn.

Our latest garage is on Perkins Street, a plan being shown in Fig. 4. Here the motorcoaches enter from Bluff Street, and exit on Perkins Street. Except for the row of columns through the center, this building works out to very good advantage. In place of the standard pits, a depressed type of floor is used, this construction being shown in Fig. 5. In Fig. 6 the movable parts of the runways are shown slid to one side for removing Twin-Coach engines.

As gasoline is one of the most important items in motorcoach operation, much attention has been given to its purchase and handling. Gasoline is being bought on a contract according to Government Specifications for Lubricants and Liquid Fuels, as stated in Technical Paper No. 323B. A distillation test is made on each carload of gasoline before it is put into the large storage-tanks. The apparatus for making the distillation test is a comparatively cheap apparatus, costing about $60. The test requires about 30 min. and is a very satisfactory test as to the actual value of the gasoline as a fuel. Any carload of gasoline that does not meet the specifications is immediately condemned and either taken away or, in some instances, is accepted at a lower price adjustment. The company has at its various garages a total storage-capacity of 156,000 gal. The fleet is using more than 7000 gal. of gasoline per day.

A typical installation of the gasoline storage is at our Perkins Street garage, where three 15,000-gal. tanks are buried in leased land at a railroad siding. The three tanks are connected with a 4-in. pipe and valves so that, from two different positions, gasoline can be dumped from the tank cars into any one of the three tanks. Two piston-pumps, each of a capacity of 30 gal. per min., are connected so that they can draw gasoline from any one of the tanks and discharge into 1500-gal. tanks which are placed in the garage 90 ft. above and 400 ft. away from the storage tanks. These

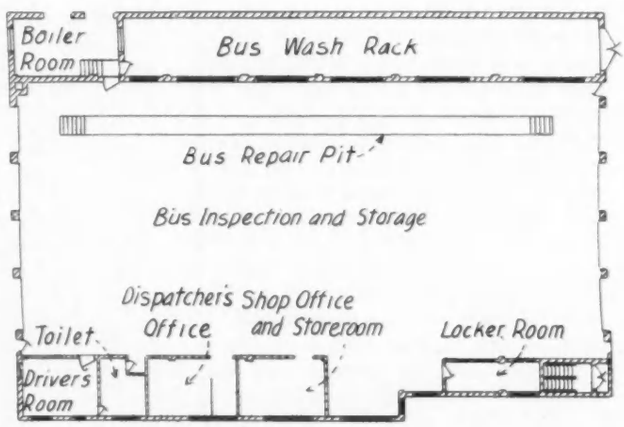


FIG. 3—PLAN OF THE EAST AKRON GARAGE

pumps are governed by remote-control switches located in the garage.

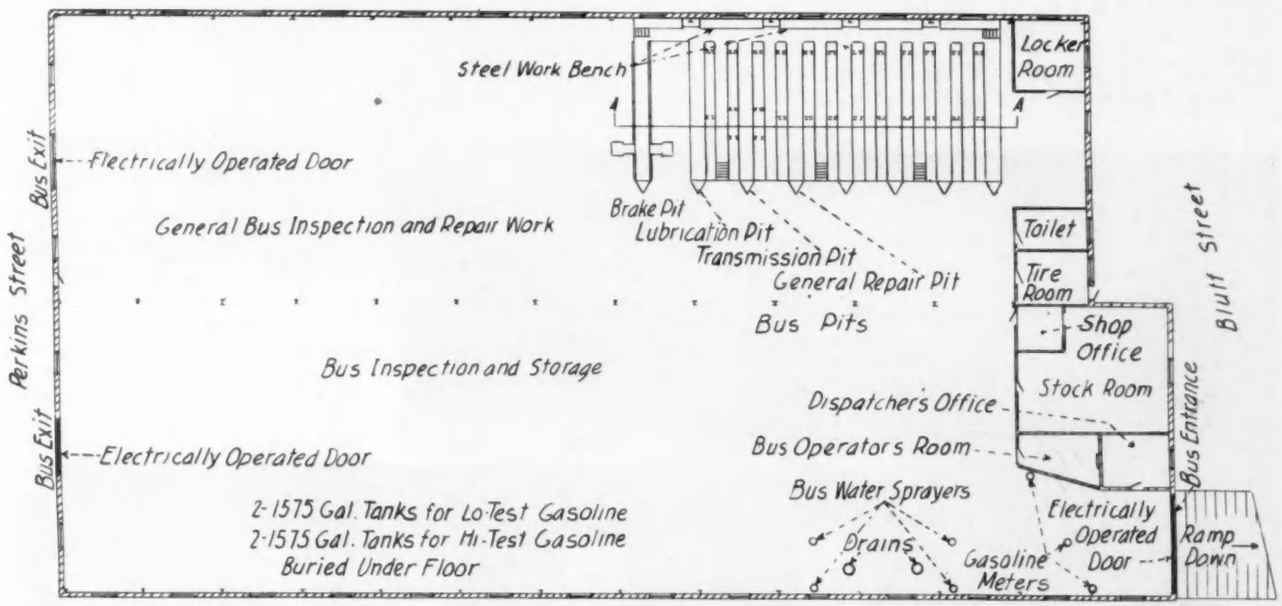
The man who operates these pumps can fill any one of the three 1500-gal. tanks that are buried under the floor of the garage. These tanks are entirely sealed up, the gaging being done with a sealed type of gage. If for any reason the operator forgets to stop the pumps, the gasoline will fill the tank and, when it starts to fill the vent pipe, it will operate a float valve which automatically shuts off the pumps and prevents the spilling of gasoline. The gasoline is drawn from the small tanks by a centrifugal pump which delivers as high as 50 gal. of gasoline per min. into the motorcoach tanks. These pumps are controlled by a weighted type of valve, the ball of which must be held up to keep the valve open and the electric current turned on. As soon as this ball is dropped, both valve and current are shut off. As a large number of motorcoaches come in at one time, it is necessary to fill the tanks very quickly; but every precaution is taken to prevent the possibility of spilling gasoline. Special cans are used to catch any spill-overs that may occur.

Although we have attempted to install the largest size of gasoline tanks possible in the motorcoaches, it is necessary, especially in winter, to refuel the motorcoaches during the day and, considering the differential that we secure by buying in carload lots, it pays us to take the gasoline to the motorcoaches in tank trucks. We therefore use three 1000-gal. tank-trucks, of the type shown in Fig. 7.

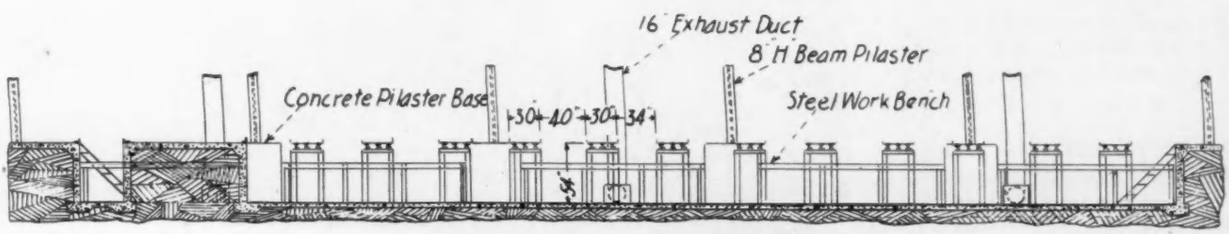
These trucks are equipped with power-driven pumps operated from a power take-off on the transmission. Although the engine is only operating at idling speed when the gasoline is being pumped, the pump will deliver about 15 gal. per min.; with the old gravity-system, only 5 gal. per min. could be put into the motorcoach tanks. This faster rate of filling has been found to be very advantageous, as the vehicles do not have to be held up as long for service. As a safety measure, the exhausts of these trucks have been carried to the roof of the cab and turned in a forward position. With the use of the power-driven pumps we have sufficient head to operate meters which accurately measure the gasoline supplied to the motorcoaches. Until this arrangement was resorted to we were never able to get very satisfactory gasoline averages. We are now able to measure accurately and know how much gasoline is being put into the motorcoach tanks.

Lubrication Procedure

Lubricating oil is also an important item in motorcoach maintenance. We are using specifications for oil as a guide in purchasing oil, but we feel that as yet there has not been a satisfactory set of specifications



Floor Plan of Perkins Street Garage



Section A-A Showing Pit Construction

FIG. 4—PLAN OF THE PERKINS STREET GARAGE

drawn up on which oil can be purchased. The first attempt that we made to buy oil strictly on specifications brought in bids for carload lots ranging from 19 to 54 cents per gal. All of the oil offered would have passed the specifications satisfactorily.

We feel that some society, association, or the Government should develop specifications that would really determine the quality of the oil so that purchasing departments would not have to depend on brand names and could buy oil in the open market the same as we are now purchasing gasoline, steel and various other commodities. It is very difficult to tell anything about the properties of the oil from any service test, as the service in which the motorcoaches are operating varies to such a great extent, and the development of wear and the formation of carbon takes such a long time to progress that satisfactory information cannot be secured from this source. Dilution, flash, fire, and viscosity tests give very little more information.

We have found that we can purchase oil considerably cheaper by carload lots, and have put in a 16,000-gal. storage for oil purchased in this way. The oil tanks are located under the floor of the Kenmore garage, and are installed so that unloading connections can be made at the coal siding near our boiler-room. With this arrangement steam can be used in the steam coils in the oil cars to warm them up so that they can be emptied in cold weather. The oil from these large storage-tanks is pumped to a 200-gal. tank installed in the roof of the garage, at a point where the motorcoaches are supplied with gasoline and serviced. This tank is equipped with a steam coil for cold-weather use. The oil then flows down to a quick-opening valve for drawing off oil and filling engines as they enter the garage.

FIG. 7—ONE OF THREE 1000-GAL. TANK-TRUCKS USED FOR GASOLINE DISTRIBUTION

An old motorcoach chassis has been equipped with a 600-gal. tank for distributing the oil to the other garages. A 300-gal. compartment at the front of the truck takes care of the new oil, a 150-gal. compartment handles the reclaimed oil, and another 150-gal. compartment at the rear of the truck is used for carrying the old oil back to the shop for reclaiming. This truck is used at one of the garages as their supply for use in the motorcoaches, and is their receptacle for engine drainings. Once a week it delivers oil and picks up drainings from the other garages.

The engine drainings, which are carried back to Kenmore garage, are dumped into a 1500-gal. tank under the floor of the garage. The pump on the oil-reclaiming apparatus shown in Fig. 8 picks the oil up from this tank and pumps it into the reclaiming machines. We have two of these machines and reclaim 100 gal. of oil per day when both are working. The oil is reclaimed for about 12 cents per gal. Aside from being slightly darker in color, it seems to be practically as good as new oil. The gasoline-service trucks are also equipped with lubricating-oil tanks which are heated from the exhaust of the engine in winter. Very accurate records are kept of the consumption of oil in all motorcoaches. These records are tabulated and comparisons are made. When the oil consumption becomes very high on any particular motor-

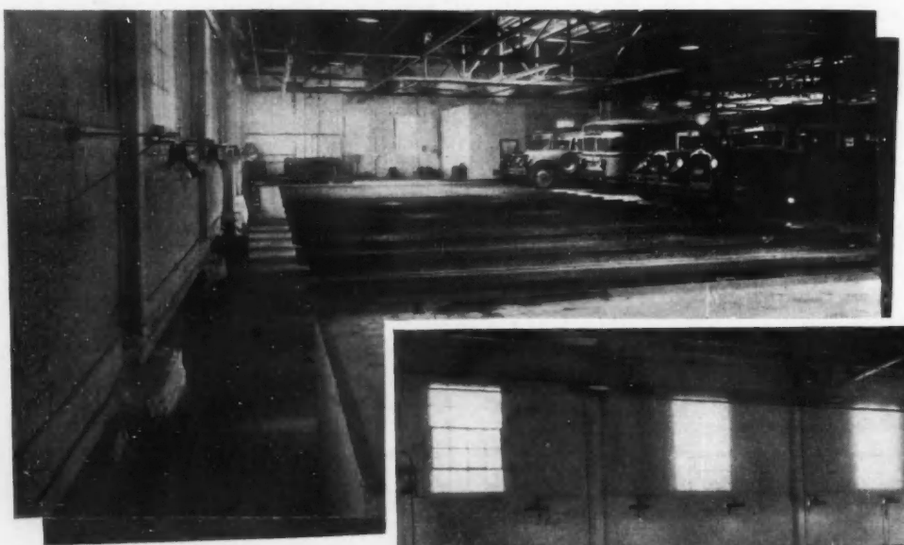


FIG. 5 — DEPRESSED TYPE OF FLOOR CONSTRUCTION USED IN THE PERKINS STREET GARAGE

FIG. 6—MOVABLE PARTS OF THE RUNWAYS SHOWN SLID TO ONE SIDE FOR FACILITATING THE REMOVAL OF TWIN-COACH ENGINES

coach, it indicates that the engine requires overhauling.

Conferences Held with Foremen

The holding of foremen's meetings is one of the methods used to raise the standard of maintenance. Immediately preceding the holding of the monthly foremen's meeting, all the monthly reports are sent to the

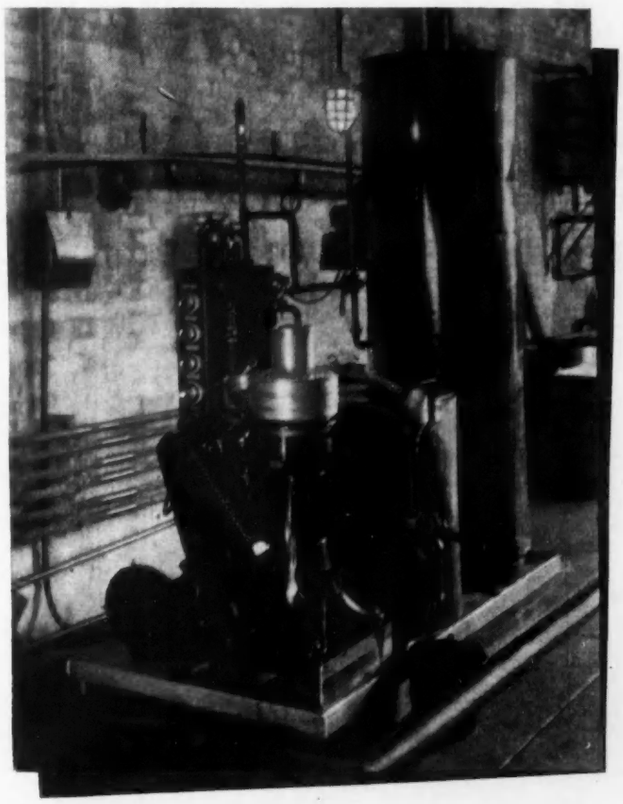


FIG. 8—OIL-RECLAIMING APPARATUS USED IN THE KENMORE GARAGE

different foremen so that they may look them over and be able to discuss and explain them during the meeting. The reports consist of:

(1) Road calls and forced stops, figured per motorcoach and per motorcoach mile, and a comparison of the different garages and makes of motorcoaches
(2) Gasoline and oil consumption of the different makes of motorcoach
(3) Labor cost, figured in dollars and in man hours
(4) Cost of the material used in the different garages, and the cost of the different makes of motorcoach
(5) Large wall-display curves of the monthly mileage, revenue, operating and maintenance costs per mile, as shown in Fig. 9
(6) Monthly progress report, made on all special work being done on the motorcoaches

The progress report, item (6), shows the number of such motorcoaches requiring the work, the number that have been completed, the number done during the last month, and the number yet to do. Discussion brings out why more progress has not been made and what can be done to push the work forward. In this way we are sure that, when any work is started, it will be completed on all of the motorcoaches.

The discussions at these meetings often bring out improvements in maintenance methods and result in a standardization of the methods of work. At the conclusion of the technical part of a meeting, the head of the accident-prevention department meets with the foremen and a review is made of every accident that has occurred during the last month. The foremen are held accountable for the safety of their men. They must explain how the accidents happen, and a discussion is held as to how to prevent their recurrence.

Clerical System Outlined

To obtain and follow up information on motorcoach maintenance, it is very important to lay out the best form of clerical system so that the information can be secured accurately with the minimum amount of work, both on the part of the garage mechanics, who are very poor clerks, and the clerical force which must tabulate and make up the reports. To have the mechanics do as little clerical work as possible, various forms have been designed that require the least possible amount of writing. We feel that data, unless summarized in some tabulated monthly report, are of no practical value.

Drivers are required to make out a daily report as to the condition of the motorcoaches, even though the motorcoach is in good condition. These reports are made in duplicate, one copy being sent to the superintendent of transportation and one to the superintendent of equipment. In each office is a file cabinet with a space for each motorcoach. As the drivers' reports are received, they are filed under the individual motorcoach number. In this same pocket are placed the reports of all inspections. Road-call forms are also filed in this same cabinet. Therefore, each of the pigeon holes in the cabinet carries a complete history of the operation of each motorcoach. When in trouble on the road, the driver telephones the transportation dispatcher, who makes out a form in duplicate, noting thereon the time he received the call. The shop department then records the time the repair men arrive at the defective motorcoach and also the time the motorcoach is again put into service. A report of the trouble actually found is made also.

The foregoing reports are tabulated under 33 headings, in a form such that, when investigations are being made at foremen's meetings, we can tell instantly how many road calls any particular motorcoach has had, or how many of any particular kind of trouble. We can also determine how many road calls any make of motor-

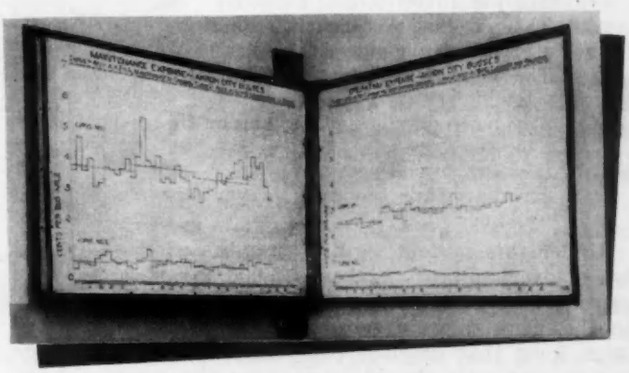


FIG. 9—TYPES OF CHART DISPLAYED AT THE CONFERENCES HELD IN THE TRAINING SCHOOL

coach has, and can refer to the file and get the actual dates of the road calls. The system therefore gives us a complete history and follow-up on the road calls and forced-stop situation. The tabulated report of forced stops and road calls is forwarded to the transportation department and other department heads. Cooperation is received from the transportation department in an effort to reduce the number of these calls.

Our inspection sheet is kept in the inspection-garage offices; each driver's defect report and all road calls are tabulated daily thereon, as well as the gasoline and oil averages. This sheet is kept in a loose-leaf binder until the date of the next inspection. When the motorcoach comes in for inspection, the sheet is removed and the back of the sheet is used by the inspectors to list the work they have done. Therefore, they have all the information as to how the motorcoach has performed since the last inspection. This acts as a very good guide for the inspectors.

Another form is used whenever motorcoaches are sent to the main overhaul-shop for repairs. This form is made out in duplicate, one copy being kept by the garage so that when the repaired motorcoaches return the men are able to check up and see if the work they reported has been properly taken care of. The columns showing the number of hours and the work done are only used in cases of accidents or fires where the cost figures may be required for the adjustment of a claim. At that time the material is entered on the back of the sheet, together with its cost. As tire work is done on a mileage basis, another form is used when tire changes are made. It often is necessary to do this work in the rain or snow; therefore, a cardboard form is used. Still another form is used very extensively for keeping track of mileage on inspections, cleaning, and practically all other classes of work done at regular intervals.

Practice for Heavy Overhauls

The shop for heavy overhauling is operated independently of the garages. The same general foreman who handles the electric-car work supervises the motorcoach overhauling. With the exception of painting and some special work that he may be doing, he does not order the motorcoaches into the shop. The garage department sends the motorcoaches in whenever they require heavy-overhaul work.

The engines are run until they show signs of distress. The engine is condemned if:

(1) It does not develop sufficient power for the service
(2) The gas fumes become excessive
(3) The gasoline records show that it is using an excessive amount of fuel
(4) The oil records show that the oil consumption is too high
(5) Any noise develops in the engine that cannot be located
(6) It shows low oil-pressure
(7) Any part fails that may prevent the use of the engine

Under this system we find that the average life between overhaulings is about 45,000 miles, while some engines have run well over 100,000 miles. When motorcoaches come to the overhauling shop, a list is made out on a form that includes everything which the garage department feels should be done on the coach. If the engine is reported, the foreman in charge of the engine department looks up the records of the engine, finding when it was last overhauled and how much mileage it has made. With this information, he is able to determine the probable amount of wear that has occurred. If he finds that the engine has run over 35,000 miles, he makes no further investigation but removes the engine and substitutes an overhauled engine. If the mileage is low, he makes compression tests, removes the head and the pan of the engine, and, if the trouble cannot be located, he removes the pistons and checks the entire engine-assembly. He may then be able to make repairs without removing the entire engine, thereby saving considerable money.

Device for Testing Bearings

On motorcoaches reported for low oil-pressure, the trouble is usually found to be a loose or broken main-bearing. An ingenious device has been developed in our

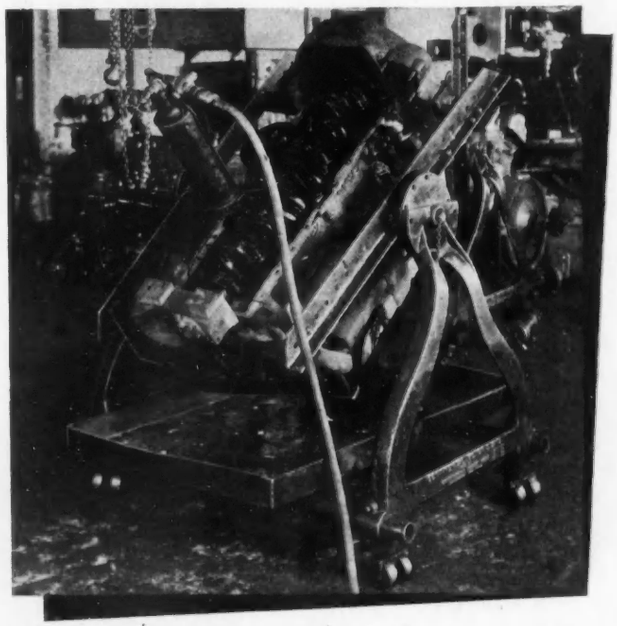


FIG. 10—DEVICE USED FOR TESTING LOOSE OR WORN MAIN-BEARINGS

shop for testing loose or worn main-bearings. A cylinder holding about ½ gal. of oil was made out of a steel pipe; this is filled with lubricating oil and connected to the oil system. After the pan has been removed from the engine a large oil-pan is put underneath to catch the excess oil. The shop air-pressure is then applied to the top of the container, and the oil is forced out through the different bearings. A man who watches can easily see from which bearing the excessive quantity of oil is coming. Fig. 10 shows this apparatus. With this device it is often possible to trace out the loose main-bearing that is starving the connecting-rod bearing.

The work of the repair shop is delegated to specially trained men who do one class of work so far as possible. The men who remove the engines and other units from the motorcoaches do not repair these units; they substitute units that have been overhauled by other men.

Engine Rebuilding Described

Probably the most highly specialized men that we have are the engine rebuilders. The crippled engine is removed from the motorcoach by the floormen and

brought into the engine room. The transmission is first removed and is sent to the transmission-repair room. The engine is then completely dismantled, all parts being cleaned either in gasoline or in a tank of hot alkaline solution. The crankshaft, cylinder-block and other parts are checked for wear. If there is sufficent stock in the crankshaft, it is mounted on the external grinder and trued up. The main bearings are all ground to the size of the smallest bearing, and the throw bearings are also ground to the smallest throw-bearing size. This is done so that, when boring, it will only require one setting of the tool to completely bore the case. The cylinder-blocks are gaged and mounted on an internal grinder. The block is bored out to the nearest 0.005 in., and the pistons, which are bought in a semi-finished size, are ground to fit. We are usually able to get about four regrindings out of a cylinder-block.

We use the same babbitt pot for re-babbitting connecting-rod bearings that is used for the armatures of street cars, the S.A.E. No. 11 bearing-metal being about the same metal that is used for armature work. The temperature of these pots is checked closely with a remote-control thermometer.

The overhauled engine is mounted in a dynamometer, of which we have two; one is home made, from a street-car motor with shunt-wound fields. This apparatus gives very good results in testing anything up to 60-hp. engines. For the larger engines, we use a 150-hp. dynamometer, shown in Fig. 11. The completed engine is mounted and dragged by the dynamometer for about 3 hr., using plenty of oil in the engine. During this time the temperature of the water running through the engine is taken, and the horsepower required to drive the engine is recorded. We have certain limits for the frictional horsepower, and this must be reached before the natural gas is turned into the engine. The engine is then run about 6 hr. on illuminating gas, developing about three-quarters of the rated horsepower of the engine.

An engine test is then made, using gasoline and taking readings of the horsepower and torque. A final reading is then taken of the compression on each cylinder to make sure that the piston-rings and valves are functioning properly. The engine is then ready for use in the motorcoach. A record is kept of the man who did the work and the number of hours required to complete it. We usually find that an overhauled engine gives us as long a life as a new engine.

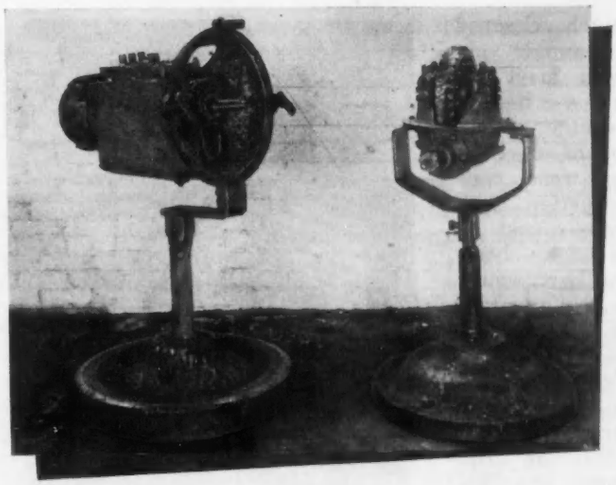


FIG. 12—SPECIAL STANDS DEVISED FOR DISMANTLING AND REASSEMBLING TRANSMISSIONS AND DIFFERENTIALS

Other Practices Described

The transmissions and differentials are handled in one department. They are completely dismantled, the gears and bearings are inspected and the parts are reassembled. Fig. 12 shows the stands that we have developed for this work. They were made from old car-wheels and their axle, make very rigid stands, and are easy to work around.

Work on the air compressors and valves is done in the air-pressure room by the same man who handles the street-car air-compressors and air-valves. The air compressors are tested by pumping against standard orifices.

Generators and magnetos are handled as part of the street-car armature-room work. The use of the magneto is being gradually discontinued. Our rule is that if magneto repairs will cost over $15, the magneto is to be taken apart and used for spare parts and a battery distributor-unit is to be substituted. Radiators are handled in conjunction with the tin-shop. Testing and washing tanks are installed, and all radiators are tested under pressure. We have found it much cheaper to do our own work, and our radiators stand up better than those repaired in local radiator-shops.

Body work is done in the street-car carpenter-shop, which is fitted with every kind of wood-working machine for taking care of any class of work. We have found that it is

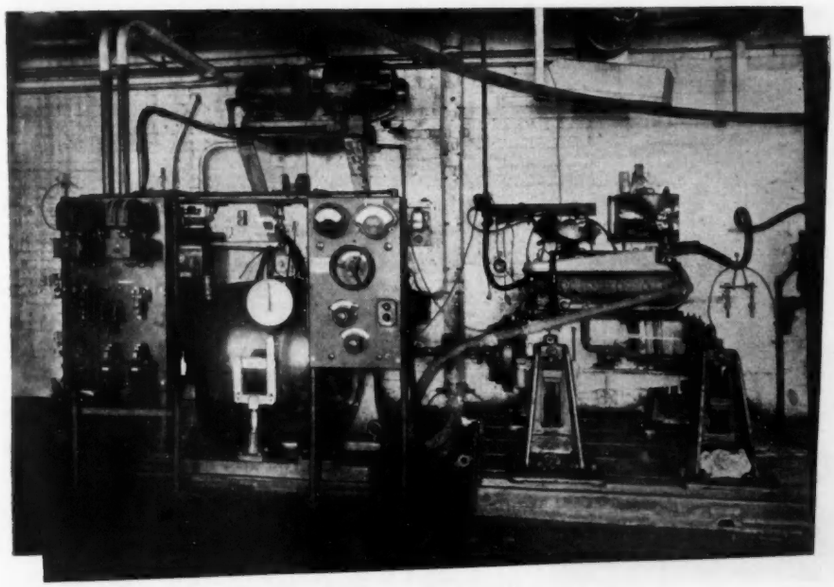


FIG. 11—THE 150-HP. DYNAMOMETER AND RELATED APPARATUS USED FOR ENGINE TESTING

much cheaper to repair our own motorcoaches, whether they be of steel or of wood construction. The repair cost of wooden-body motorcoaches, especially where the posts are covered with aluminum, is far greater than that of the metal and ply-metal-body motorcoaches. There seems to be no way of preventing the deterioration of the wooden-body motorcoaches, but if the painting is followed up properly in the metal-body motorcoaches there seems to be no limit to their life.

FIG. 13—LARGE PAINTING-BOOTH IN WHICH EXTERIOR PAINTING OF THE VEHICLES IS DONE BY SPRAY METHODS

All exterior painting is done by the spray method. The paint shop is equipped with a large spray-booth, shown in Fig. 13. The coach windows are covered with a preparation composed of soap chips, glycerin and whiting. We try to arrange the color scheme so that as little masking as possible will be needed. Usually this can be arranged so that one masking will do. The painting of the destination signs, where a large number are required at one time, can be very cheaply done by the silk-stencil method. If only a few signs are required, cheaper pasteboard stencils are used. The quick-drying enamel-paints are found more satisfactory than the lacquers. This material can be applied over either lacquer or old paint and gives no trouble on wood or moldings. It does not clean up quite as easily as the lacquer, but we feel that the results are somewhat more satisfactory.

A well-equipped school for motorcoach drivers has been a great help in educating them to avoid abuse of the equipment. An old engine, cut out to enable the drivers to see its working parts in action, is mounted on a stand and can be turned over and moved around for the convenience of the class. Fig. 14 shows plan and end views of the engine.

The Twin-Coach engine can be removed from the motorcoach as quickly as any other make of engine, if proper facilities are available. A pit is used that is similar to the pit used for removing armatures from street-cars (see Fig. 15), having a cross-pit at right angles to the main pit. The motorcoach passes over the auxiliary pit on two oak planks which are bound with angle iron for guards and are removed after the motorcoach has been spotted. An air-actuated jack mounted on a small car is provided which operates on a steel track laid in the cross-pit. This jack raises the engine and allows it to be moved clear of the supports. It is then lowered clear of the motorcoach and the car is moved out from under the motorcoach to where the traveling crane can pick the engine up.

Two air-pressure hoists sunk in the floor are provided; they are competely flush with the floor when not in use. These air cylinders are spaced so that, when they rise, the entire rear assembly can be removed from the motorcoach. Fig. 16 shows an electrically-operated hoist which is very convenient for removing rear axles and transmissions.

Self-Maintenance Methods Used

When our fleet was small the company sent to outside repair shops a great amount of work such as magneto, generator, and radiator-repair work and certain classes of welding; but, as the fleet became larger, we soon found that this work could be done much cheaper and more satisfactorily by our own trained men. We now do all our own generator, magneto, distributor, radiator and welding work. At present, the only work that we send outside is our spring-repair and heavy storage-battery work. We have battery-charging generators in all our garages, and charge the batteries there unless they need heavy repairs. We believe that we should do all our own spring-repair work, and we probably will do so in the near future.

Much thought has been devoted to the development of an adequate inspection-system for the various types of motorcoach. We have made frequent changes and improvements in the system. We are inspecting on a 1000 and on a 2000-mile basis at present. The 1000-mile inspection is a very complete inspection and greasing. The 2000-mile inspection includes all work done at the 1000-mile inspection and certain additional features.

Brake adjustments are made over brake-adjusting pits, and brake-testing apparatus is provided. This adjustment is not done at the same time the inspection is made, but most of the motorcoaches in heavy service are getting a 5-day brake-adjustment and inspection.

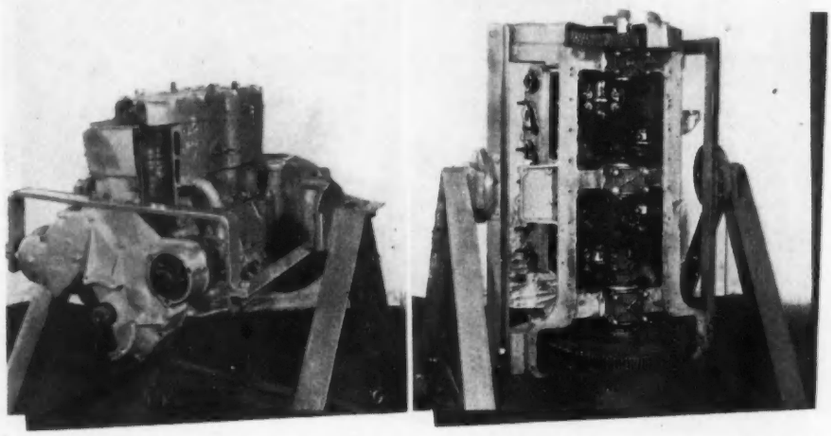


FIG. 14—MOVABLE STAND ON WHICH A CUT-OUT MODEL OF AN ENGINE IS MOUNTED TO ENABLE DRIVERS TO SEE ITS WORKING PARTS IN ACTION

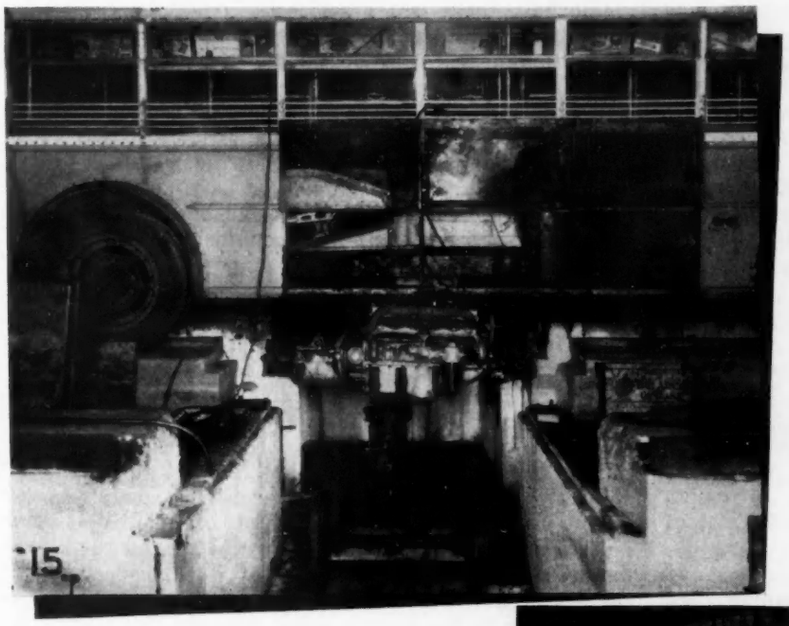


FIG. 15—TYPE OF PIT USED FOR REMOVING ARMATURES FROM STREET-CARS. A CROSS-PIT RUNS AT RIGHT ANGLES TO THE MAIN PIT

At this time accurate records are made as to the pounds of drag on each wheel, with and without brakes applied. Charts are supplied showing the braking drag required, based on the weight of the motorcoach and its make, so that the men can make the proper adjustment. Records are kept showing the pressure that was secured both on the service and the emergency brakes. These records are filed so that, in case of an accident, the company can use them to show the condition of the brakes.

An economy has been effected by the use of washable wipers. These wipers are purchased in standard size, 18 x 18 in., and issued to the men. Then, by using an exchange system, each man is supplied with all the clean wipers he may require. He is held strictly accountable for the original number of cloths that were furnished him. This not only results in considerable saving in money, but is one of the biggest factors in keeping the garages clean and satisfactory to the insurance company.

A reclaiming department has been developed to inspect parts before they are scrapped. The general foreman passes on whether it would pay to repair an individual part.

A check was made on the spark-plug consumption which showed that the average life was less than 5000 miles. We then put in an exchange system, giving each road mechanic a certain number of spark-plugs and holding him responsible for the number taken out. As he changes spark-plugs in the engines, he brings them to the storeroom for exchange. The old spark-plugs are cleaned, adjusted and tested under a 90-lb. air-pressure. This system increased spark-plug mileage well up to 10,000 miles.

When motorcoaches become obsolete they can be used to advantage for service trucks and special pieces of apparatus.

FIG. 16—AN ELECTRICALLY OPERATED HOIST FOR REMOVING REAR-AXLES AND TRANSMISSIONS

FIG. 17—REMODELED MOTORCOACH USED AS A SALT-SPREADER

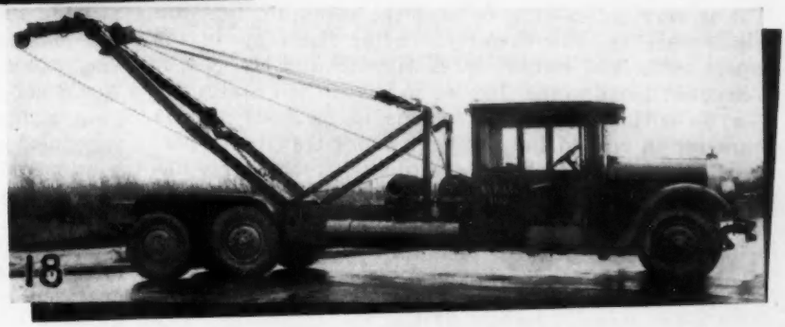


FIG. 18—HEAVY-DUTY WRECKING-TRUCK FOR INTERURBAN SERVICE
This Was Built from the Chassis of a Double-Deck Six-Wheel Motorcoach and Designed Especially for Bad Interurban Wrecks of Street-Cars or Motorcoaches

It is a very simple matter to cut down the long wheelbase and make whatever changes are necessary. Fig. 17 shows an old motorcoach being used as a salt spreader. We have three motorcoaches transformed in this way. A power take-off has been installed on the transmission and this is connected to a three-speed Chevrolet transmission, which in turn is connected through a drive-shaft to a Ford axle mounted vertically in the truck. The upper part of the axle carries a wrought-iron wheel for breaking up the salt, the lower end driving a cone for spreading salt. By the use of a touring-car transmission, any speed can be obtained regardless of the movement of the truck. A tapered steel-box holding about 3 tons of salt is mounted on this truck. There is also a lever arrangement which controls the flow of salt, so that the driver has full control of the distribution. These three salt-trucks are able to cover the city very quickly after a snow or sleet storm. They salt the points where the motorcoaches have to stop, and all hills. Although Akron is a very hilly city, we have not used a set of chains in the last four years.

We have a city-service wrecking-truck and Fig. 18 shows our latest type of heavy wrecker for interurban service. This wrecker was built from the chassis of a double-deck six-wheel motorcoach. It was designed especially for bad interurban wrecks on either street-cars or motorcoaches. It has a very large cab to accommodate the wrecking crew. The long wheelbase makes it possible to lift heavy loads without danger of raising the front end. For side lifts, the rear pulley is pivoted on a hollow shaft so that the line from the winch passes through the shaft on which the boom wheel is mounted. The pulley is therefore able to turn at any angle so that, when a motorcoach or other object is to be lifted at an angle to the boom, there is no binding on the side of the pulley.

We have made it a practice to inspect every motorcoach system that we can. A comparison of inspection systems and shop practices is always valuable. Comparisons of men, or man-hours per motorcoach or per motorcoach mile, often develop interesting figures. When one talks with the heads of motorcoach companies, they say that they are following certain methods of inspection and do not have, or have entirely cured, certain troubles. Then when one looks over their equipment, talks to their men, and looks over the scrap pile, it is apparent that they do not know their own equipment.

It is very easy for a maintenance executive to deceive himself about his inspection schedules and repair work. He may sit in his office and lay out a wonderful method of inspection, and figure out limits of wear and condemning points for his repairmen, but it is one thing to tell men to do work and another and harder thing to make sure that they do it and do it correctly. To follow the work properly, careful checking up must be carried on. Records of road calls, dead motorcoaches, gasoline and oil averages, and costs per motorcoach, all help to check the work, especially if the inspection is so segregated that the defect can be traced back to the man or gang that did the work. A personal follow-up by some supervising man is also necessary. When the question came up of whether the night men were draining the air tanks every night in winter, as they were supposed to do, we suggested to the foreman that he plug a couple of the cocks with toothpicks and see if the night men found and removed them. The foreman felt that this was a very mean trick and should not be done. We are afraid our morals are very bad on this score, for we are constantly setting traps of this kind and going over the motorcoaches on which an inspection has just been completed to see that its every detail has been carried out.

THE DISCUSSION

CHAIRMAN F. C. HORNER[2]:—Some years ago I inspected the operations of the London Omnibus Co., England, which at that time was, and still is, the largest motorcoach operation in the world and one of the largest motor-vehicle operations of any kind. The company had a very thorough system of inspection and repair methods with regard to maintenance, and it probably is the most scientifically conducted motor-transport undertaking anywhere.

It is very interesting to note the evolution that has taken place in this Country. After listening to the papers by L. V. Newton[3], H. B. Hewitt[4] and Mr. See, it is brought home to me that we in the United States are well up with our English cousins in methods of this character in regard to passenger motor-transport operation. That was not true here to any great degree until recent years.

Mr. See's method of buying gasoline and oil, as stated in his paper, interests me. I suppose that this method is employed very largely by the large-scale operators who operate in a scientific manner; but Mr. See has brought that fact sharply to our attention. Opportunity is given in Mr. See's and Mr. Hewitt's[4] papers to make a comparison between wholly mechanical and gasoline-electric vehicles.

J. A. HARVEY[5]:—The method used by Mr. See for the installation of grease racks, inspection racks and the like is interesting in that he has utilized the facilities at hand such as channels, pipe and other material available on any property of this type, without purchasing very expensive material and equipment which probably would not produce any better result. Instead of scrapping equipment which is worn out so far as regular scheduled operation is concerned, he has used such equipment in other practical ways—such as for gasoline trucks, tow trucks, and the like—and has thus eliminated the necessity for purchasing new equipment, thereby saving his company large sums by avoidance of high depreciation-rates. Due to the low mileage operated by this equipment, maintenance is not likely to be a major item. His paper discusses thoroughly the possibilities inherent in using materials at hand so as to produce the best results, and is especially helpful

[2] M.S.A.E.—Assistant to the vice-president, General Motors Corp., New York City.

[3] See S.A.E. JOURNAL, January, 1931, p. 89.

[4] See S.A.E. JOURNAL, January, 1931, p. 84.

[5] M.S.A.E.—Operating engineer, Pittsburgh Motor Coach Co., Pittsburgh, Pa.

to those of us who must adapt our plants and equipments to the latest trends without large investment-expenditures.

Oil-Filter Efficacy Questioned

A. J. SCAIFE[6]:—Has Mr. See analyzed the difference in cost between reclaiming oil from the entire fleet as compared with using oil filters and other devices of that kind?

P. V. C. SEE:—We have tried three different types of oil filter on the motorcoaches and have as yet found none of them satisfactory. Our oil-reclaiming apparatus has given entire satisfaction.

QUESTION:—In what respect are oil filters that you have tested unsatisfactory?

MR. SEE:—The felt or other material clogged the pipes and became choked with dirt and foreign material within a very short time.

A. F. COLEMAN[7]:—Previous remarks indicate that oil filters for use on motor-vehicles need to be defended. I will defend the oil filter on the basis of an experience I had in conducting a test at the Indianapolis race-track.

We used three standard eight-cylinder cars, one of which was equipped with an oil filter and a cooler. The test was in August and the atmospheric temperatures at the track were about 94 deg. fahr. during the day and as low as 54 deg. fahr. at night. During the run the crankcase temperatures on two of the cars which were not equipped with oil filters reached about 240 to 250 deg. fahr. The test was to drive the cars at a speed of about 60 m.p.h. for 8000 miles without stopping.

The one car equipped with the oil filter and cooler used exactly one-half the quantity of oil that either of the other two cars used, the total distance being actually 7300 miles when the test ended. The temperature in this one car was always from 15 to 20 deg. fahr. cooler in the crankcase than in the crankcases of either of the two cars not equipped with oil filters. The oil was left in the cars for the entire test, only enough oil being added to keep the oil level satisfactorily high.

During this test the viscosity of the oil actually increased. Because of the high temperatures at which the cars were operated, there was no dilution and it was necessary in one car to change to a lighter grade of oil to take care of this increased viscosity, this being the probable reason for the slight increase in viscosity already mentioned. When old crankcase oil is redistilled, its natural process through the engine burns out some of the lighter ends of the lubricating oil. When the oil is reclaimed, as the cause of the dilution—which is the heavy end of the gasoline—is removed, the reclaimed oil naturally will have a higher viscosity.

MR. SCAIFE:—Mr. Coleman introduced another factor into the discussion when he mentioned the cooling factor. As to the entire cooling subject, using both an oil filter and a cooler, no one knows which of the two devices is doing the work. We know that we can keep lubricating oil cold to the extent of say 15 to 20 deg. fahr. and that this makes a wonderful difference in the oil consumption.

J. F. WINCHESTER[8]:—Mr. See specified oil which he can buy for 19 cents or for 54 cents per gal. but he failed to state what grade he bought. I wonder if he bought the 19-cent grade and if this caused the oil lines to become clogged so rapidly.

We are making rapid strides in automotive design. The average passenger-car is fitted with oil-filtering devices and also with air-cleaning devices. From the samples of oil that I have seen tested and the fact that the vehicle has a longer life today, I have no doubt that these devices do a great amount of good.

Regarding Mr. See's statements concerning the buying of gasoline according to specification, knowing the rapid advances now being made in design and the tendency toward higher compression, I wonder whether Mr. See divides his fleet in any way so that engines having high compression use gasoline having an anti-knock value, which should show greater economies even though a premium were paid for it?

Also, Mr. See says that he holds his foremen individually responsible for accidents. How is this accomplished? We lecture our foremen and try to reduce the number of accidents to the lowest possible point. It seems difficult to do otherwise than to call to a foreman's attention other things than mere infractions of rules, so that he will be alert to continue the educational features of his work.

P. V. C. SEE

MR. SEE:—In reference to the price paid for oil, our management was rather surprised when it found that the range of price was so great. Originally we paid about 34 cents per gal., but now we are paying slightly more. We purchase what originally was termed New Navy Gasoline, which is a low-test gasoline having an end-point of 437 deg. fahr.

Referring to antiknock-gasoline usage, on the later types of engine I believe its use might make some difference; but for the fleet as a whole, since we have both old and new vehicles, I cannot see that we would gain by buying antiknock gasoline unless we divided our fleet into the old and the new types and used antiknock gasoline only on the newer types of vehicle. As to reduction in the number of accidents, if our men repeatedly have accidents we punish them or lay them off.

H. P. SPARKES[9]:—Concerning the present spark-plug equipment used on transportation vehicles, some of the manufacturers have stated that some spark-plugs wear out quickly with the antiknock fuel.

MR. SEE:—We have used antiknock gasoline in dynamometer tests and in our fleet of touring cars, but we have noticed no particular trouble caused by spark-plug burning.

Use of Reclaimed Oil Discussed

R. H. VAN NESS[10]:—What is Mr. See's practice regarding the use of reclaimed oil? What policy regarding depreciation does he adopt; a low depreciation and high maintenance-cost, or high depreciation and a low maintenance-cost?

[6] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland, Ohio.

[7] M.S.A.E.—Manager of the motor-vehicle department, Standard Oil Co. of New York, New York City.

[8] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark, N. J.

[9] Engineer, Westinghouse Electric & Mfg. Co., Pittsburgh.

[10] A.S.A.E.—Superintendent of transportation, City Ice Co. of Kansas City, Kansas City, Mo.

MR. SEE:—At first, I doubted that the reclaimed oil was as good as new oil; but, after sending samples to various testing laboratories and making tests ourselves, we found that the viscosity, the flash and the fire tests can be restored and that the oil seems perfect in every way except that it is slightly darker. We first used it separately simply to compensate for lost oil, but now we dump it into the new oil.

Regarding depreciation, some of the coach companies have claimed that ten years is the proper depreciation period. It is a matter of bookkeeping with our company, and we depreciate each mortorcoach on the basis of four years. Many of our motorcoaches are eight years old, but the depreciation is set on the basis of four years. Our reason for this practice is that many of the vehicles will be retired on account of obsolescence; some have been retired in less than two years. The vehicles which are eight and ten years old are as good as they were originally, but they are of an unsuitable type. The steps are high, the bodies are high, they do not appear well and are not as efficient or as strong as the newer types.

F. C. HORNER

H. B. HEWITT[11]:—We have now had three years of experience in reclaiming used oil. Our plant has a capacity of 200 gal. per day. When we began, we mixed new oil and reclaimed oil in equal proportions but, through chemical-laboratory control, our analyses began to show that the reclaimed oils were just as good as the new oils and, in some cases, somewhat better because the extra refining-process gave better results. In 1929, we reclaimed 30,000 gal. of oil, 100,000 lb. of waste taken from the car journals in subway and trolley-car service, and 27,000 lb. of wiping rags.

As an example of an extreme case, a certain taxicab company in this Country buys no new oil. One of its trucks calls on the service stations and garages to pick up waste oil to be put through a used-oil reclaimer. This company states that the reclaimed oil costs 5 cents per gal. It has been used exclusively for two years.

QUESTION:—What does it cost to reclaim oil?

MR. HEWITT:—Delivered at the garage, it costs 11 cents per gal. This includes hauling the oil to the central reclaiming plant and back to the garage. Based on our experience, we would recommend the installation of a small oil-reclaiming plant in each garage so as to make each foreman responsible for the reclaiming of oil used at his own garage.

MR. WINCHESTER:—Regarding the reclaiming of oil, does the process used take care of dilution, does it take the dirt out, and does it correct the oil for acid content? How long is the oil operated in the vehicles between changes? Were the engines operated just before the oil was changed?

MR. SEE:—We change oil after each 2000-mile period of operation. We use the De Laval system, which removes all of the dilution, and the reclaimed oil has the same viscosity, flash and fire-test values as has the new oil. We have not tested for acidity.

MR. HEWITT:—We use the Sharpless process. Dilution is removed by a still and from it we obtain a very effective cleaning agent for various purposes connected with the motorcoach, taxicab and trolley-car operations. We have checked the amount of acidity at numerous times and found so little that we pay no attention to it at present.

MR. WINCHESTER:—Do the oil filters and oil lines clog up?

MR. HEWITT:—We had oil filters installed on 225 coaches and they gave so much trouble that we removed them. This led us into reclaiming the oil. We tested numerous different types of oil filter and all gave about the same results. Our operation improved greatly after the filters were taken off.

MR. SCAIFE:—I think there is a place for both of these systems. However, I question whether it would pay to have an oil-reclaiming plant for say five or six vehicles. In such a case the owner probably should have some sort of oil filter.

Mr. See says that his company drains off the oil after each 2000-mile period of operation, but I believe that the practice of the Cleveland Railway Co. is to drain the oil every two weeks from each vehicle, regardless of whether it has operated in the meantime or not.

MORSE REW[12]:—Within the last eighteen months we have abandoned trying to keep an exact record of mileage with regard to draining the oil. But this does not apply to what we term our *A* and *B* inspections. We have two main types of inspection aside from the minor nightly inspection. First comes a weekly inspection, and at that time the oil in all the vehicles is removed from the crankcase. We do not drain the oil from the differential. We believe our practice is more satisfactory in that we are less apt to make a mistake and fail to change the oil on some vehicle.

We reclaim all of our oil. If one of our engines has run but a few miles during any particular week we have not lost much because we are reclaiming all of the oil. Our experience regarding the reclaimed oil is the same as that of Mr. See and Mr. Hewitt; that is, it is entirely satisfactory. We find that the viscosity is somewhat better than was the viscosity of the original oil, and the other properties already mentioned are also satisfactory. Regarding acidity, there has been so little trouble on this account that we now entirely disregard it.

[11] Engineering assistant to vice-president in charge of operation, Mitten Management, Inc., Philadelphia.

[12] Superintendent of the motorcoach department, Cleveland Railway Co., Cleveland.

Motor-Vehicle Performance Indicating and Recording Devices

Discussion of Carl W. Stocks' Transportation Meeting Paper[1]

THE AUTHOR'S purpose is to enlist greater interest from the manufacturers in the development of more substantial instruments and to point out how these instruments can be used by all classes of motor-vehicle operators. Dividing such instruments into two groups, he sketches a background for the solving of specific problems relating to their use and then describes devices which facilitate operation. Certain instruments intended as a check on operation and designed to furnish definite information through the medium of charts or tapes are commented upon, as well as devices that are primarily designed to assist the driver in more intelligent vehicle-operation.

Several types of recording devices now available are analyzed, and descriptions are given which illustrate the benefits derived from their usage. The reliability of speedometers in general is doubted unless excessively expensive maintenance methods are applied to them. The author then states what other motor-vehicle carriers are doing to maintain conventional-type speedometers in reasonably good working order, on what mileage basis such instruments are overhauled, and to what extent other types of speed-indicating or mileage-recording devices are used, citing the information as obtained from a questionnaire issued by *Bus Transportation* in an attempt to secure data on the subject.

He mentions other types of instrument, including tachometers, states their advantages and disadvantages, and advocates the development and use of a device to count engine revolutions accurately, these data to be used in preference to reckon the life of an engine and its allied operating accessories in terms of vehicle mileage. In other words, the author urges the development of an accurate engine-revolution counter and the rating of engine performance by engine revolutions.

New types of instrument and applications of existing devices are described and discussed by representatives of instrument manufacturers and motorcoach operators. Standardization of instruments is stressed, as well as the need for a standard to measure their performance, and as a result of this discussion the appointment of a committee to standardize on the form and arrangement of instruments used on motorcoaches as well as criteria of performance was voted.

Speedometers are criticized and defended by several speakers and in this connection the substitution of a tachometer indicating the engine speed and registering the total number of revolutions for the speedometer as an indication of when maintenance work should be done is advocated. Instruments that would function automatically to regulate the speed of the vehicle, especially when rounding a curve, are mentioned as a very desirable addition to the motorcoach instrument-board. The value of instruments and their records in various phases of motorcoach operation and maintenance is discussed.

EDWARD L. VIETS[2]:—I think that if people who drive trucks were all members of the Society, we would sell many more recorders than we do. The real fact, however, is of course, that the average hard-headed business man in charge of motor-trucks or motorcoaches is not graph minded, so to speak. Types of chart, such as ours, more or less stagger him, although considerable information can be obtained from them. The Servis Recorder, which I represent, gives less information, I often think, than any recorder made. It merely tells when the vehicle is running and when it is standing still, and yet we do find people who are not willing even to get this information. However, if they were studiously minded, like the engineers, they could get much.

For instance, take a truck that stands 1½ hr. at the loading platform. If that is looked into studiously, a chain of events may be found with three or four links in it that may even go back to the credit manager approving orders or it may go back only to the office. Because of this chain with a weak link in it, these expensive trucks are standing out front wasting 1½ hr. A man having seven or eight trucks might find out that, on the average, they finish the day's work at four o'clock, whereas quitting time is at five, and that, because only 1 hr. is left, sending them out on another delivery hardly pays. Yet if he will study the chart and really bring things back home to himself, he can find that by cutting down the length of the routes, he can get all the trucks back at 3:30, in time to make another delivery worth while.

EDWARD L. VIETS

Briefly, these are the facts a man can get by studying a chart. The average man, however, who uses Servis recorders, or any other kind of recorder, merely puts his thumb on a big delay of 1, 1½ or 2 hr. and eliminates that. He does some good by doing that, to be sure,

[1] The paper was published in the November, 1930, issue of the S.A.E. JOURNAL, p. 529. Mr. Stocks is a Member of the Society and is editor of *Bus Transportation*, New York City. The abstract that preceded the paper when it was published is reprinted for the convenience of the reader and is supplemented by a brief summary of the discussion.

[2] Sales manager, Service Recorder Co., Cleveland.

but he is not chart minded. All he does look at, as a matter of fact, are the big delays. That is why, when I see so much detail shown on the chart, which looks so good and could be made of so much use, I think it is a shame that this is not done.

But they do find these big delays, even 20 or 30 min., which are generally habitual delays. They find out the strangest things imaginable, such as drivers going to ball games for 2 or 3 hr. at a time, or reporting in the morning on time with their trucks, going out with a load, driving to their houses for breakfast and staying there 2 hr., as often happens. This is the kind of delay that runs into money, when we consider that the truck is worth about $4 per hr., so that almost any instrument of this kind would pay for itself in less than 2 weeks.

Recording and Indicating Types

R. T. ABRELL[a]:—Motor-vehicle transportation in industry and as common carriers has been accepted as a vital part of our general transportation system along with the steam and electric lines. The rapid transition from the hit-or-miss methods of operation in the younger days of the industry to the economically sound business basis of today has of necessity required the production of instruments and devices that will diagnose and record certain factors and statistics governing the movement and maintenance of the vehicles. To operate efficiently, economically and profitably, every item that contributes to operating expense must be studied and accurately determined.

The Ohmer Fare Register Co. has, through its 30 years of experience in developing and marketing indicating and recording devices and systems essential for the successful operation of electric-railway lines and taxicab companies, anticipated the demand for certain devices for obtaining accurately the variable operating data as relating to motorcoach and truck operation that until recently has been a matter of guesswork. The instruments produced vary from the simple hub-odometer mileage-recorder to the more complicated instruments, the Recordograf and Autograph, which measure and record time, mileage, speed, and number and duration of stops. These instruments can be classified into two separate divisions: (*a*) those producing charts or graphs and (*b*) those that indicate but do not produce written records.

Among those coming under the first classification is the Recordograf which was illustrated in Fig. 4 of the paper. The operating mechanism combines a clock movement with a slow-speed flexible driving-shaft attached, through a calibrated gear-reduction, to the transmission, the front wheel or propeller-shaft. This is mounted on a malleable-iron base and is cushioned from road shocks by rubber shock-absorbers interposed between it and the base. A hinged heavy-steel weatherproof cover, secured to the base by a lock to prevent tampering with the tape record, encloses the entire mechanism.

Cross-section tapes, aproximately 63 in. long and divided into 36 hourly periods, record vehicular operation. The hourly graduations are subdivided into 5-min. periods, enabling time to be read in fractions of a minute. The width of the tape is divided into eight equal spaces, each denoting ¼ mile. For slower-moving vehicles, we have developed a 2 to 1-speed clock mechanism that enables the time and speed factors to be analyzed more closely. Vehicle speed is gaged by the angle the recorded oblique mileage line makes with the bottom of the tape; the sharper the angle, the faster the vehicle is traveling.

Fig. 1 is a scale to determine the vehicle speed accurately from the tapes. The tape is placed under the scale and moved along until the oblique line designating the speed to be read coincides with a calibrated line on the scale.

The Recordograf serves a two-fold purpose for analyzing motor-vehicle operation. First, the speed and mileage statistics gathered from the tapes are used by the maintenance department as the basis of tire-mileage contracts, for vehicle maintenance on an exact-mileage basis and the elimination of unnecessary maintenance expense due to overspeeding. Second, the data from the tapes are used by the traffic department in building and maintaining schedules, for analyzing movements of vehicles enroute and selecting the equipment that is best suited for particular runs. Terminal starters and

[a] Assistant vice-president, Ohmer Fare Register Co., Dayton, Ohio.

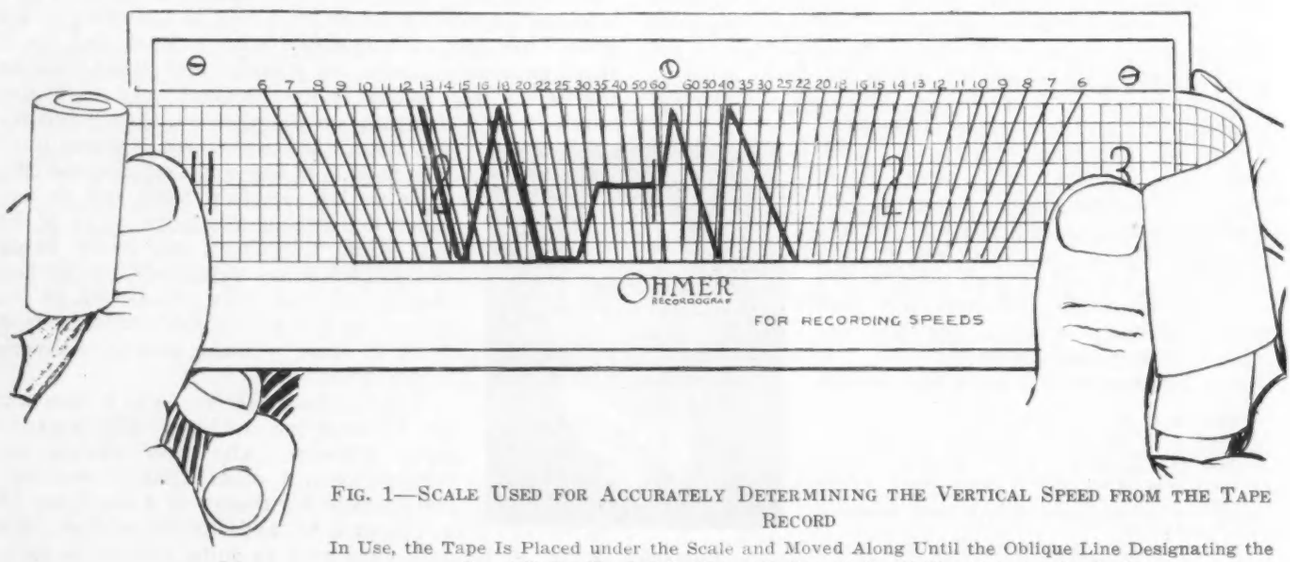


FIG. 1—SCALE USED FOR ACCURATELY DETERMINING THE VERTICAL SPEED FROM THE TAPE RECORD

In Use, the Tape Is Placed under the Scale and Moved Along Until the Oblique Line Designating the Speed To Be Read Coincides with One of the Calibrations on the Scale

checking personnel can be reduced or released for other duties. The tapes are very valuable in checking testimony in the event of speeding or an accident or collision that might involve litigation.

The Ohmer Autograph records daily on a circular paper chart the number, time and length of journeys and stops, average speeds and the number of miles of every trip and total miles traveled. It comprises a clock mechanism together with a revolving disc and a recording device. The instrument is fitted with an odometer attachment which, together with the recording stylus, is driven through a calibrated gear-reduction attached to the transmission gearbox. All driving connections are sealed and are weatherproof and tamperproof.

On the paper chart, which makes a complete revolution in 12 or 24 hr., the stylus describes concentric circles when the vehicle is stopped and radial arcs when it is in motion. Each hourly period is divided into six 10-min. intervals. A small Vibracorder attachment records the running and idle time on the inner circle of the chart, thus furnishing a running and idle-time record of vehicle movement if for any unforeseen reason the driving mechanism should happen to be disconnected. The chart is divided radially by five concentric circles, the distance between circles denoting 1 mile of vehicle movement.

A 72-hr. clock on the outside of the casing assists the driver in seeing that his orders are executed punctually and according to the same timepiece that is responsible for the records on the chart. Therefore, arguments cannot arise on account of the difference in the time of various clocks.

Another instrument of this same general class is the Vibracorder, a recording instrument without any driving mechanism, which was shown in Fig. 2 of the paper. It utilizes a chart for recording vehicle movements in a vertical or horizontal plane, a stylus moving over the surface of the chart and being actuated by the vibration of the vehicle when moving. A tell-tale device is incorporated in the instrument to show on the chart the number of times the instrument has been opened. The whole mechanism is enclosed in a locked dustproof Bakelite case.

Ohmer graphic-recorder charts and tapes tell

(1) Whether or not the vehicle is being utilized to its full capacity
(2) What a fair day's work should be
(3) How unnecessary overtime and mileage can be avoided
(4) How to decrease the proportion of empty runs
(5) How and by what time the vehicles are ready for work on each separate day
(6) The way vehicles are being handled
(7) How to obtain better performance, although the cost of supervision is low
(8) If the present fleet of vehicles can be reduced to a smaller number of units and maintain more efficient service

The non-printing mileage recorders are the hub-odometer and the odometer. The former is simply and ruggedly constructed to meet the hard service-conditions and is attached to the front wheel of the vehicle in place of the usual hub-cap. The device registers forward whether the vehicle is running forward or backward. The six large numerals on the dial are always right side up, regardless of the position of the wheel, and give a total of 99,999.9 miles, after which the dials automatically return to zero and begin to register again. Hub-odometers are made for all models and makes of car, truck, trailer and tractor.

The odometer is a mileage meter that is driven through a gearbox attached to the speedometer outlet in the transmission gearbox of the vehicle. The speed of the driving mechanism is reduced to 63 revolutions per mile, this slow speed practically eliminating the damage due to friction and excessive-speed vibration. The maximum registering capacity is 99,999, the numerals automatically resetting to the zero position. The covering of the mechanism is tightly sealed to prevent tampering. A special method of sealing the driving equipment which eliminates the possibilities of disconnecting the drive at the transmission or odometer head was recently developed for a large fleet-owner in the Philadelphia territory.

R. T. ABELL

A special type of odometer for printing the mileage readings on inserted cards was recently developed for use where a printed record of mileage only is required. Another recent special adaptation is for counting vehicle-engine revolutions, as shown in Fig. 20 of the paper. This instrument, by a positive drive through proper gear-reduction connected to the oil-pump or water-pump of the engine, records the total revolutions of the engine in a ratio of 1000 to 1. It was developed to be used in conjunction with the Recordograf by a large oil company in checking engine revolutions with total mileage covered during gasoline-consumption tests. This instrument may have a use in placing powerplant maintenance and inspection on a more equitable basis by recognizing idling and low-gear operation instead of only using actual vehicle-mileage operated.

In the last few years more attention has been given to developing suitable instruments for indicating and recording vehicular performance. More rapid and useful development work with less waste and at less expense can only be accomplished by the operators and manufacturers of vehicles closely cooperating with instrument makers in working out their problems.

Railroad and Motorcoach Operation Compared

H. P. SPARKES[4]:—I wish to congratulate Mr. Stocks on his paper, because he has opened a subject that has been allowed to grow without considering requirements. First, transportation vehicles of the motor-driven type had no instruments, and the operation of the mechanism was more or less a mystery. Today we have a conglomeration of instruments with no facts or fundamentals guiding this application. If we used one each of all of the various instruments designed for automotive use on one motorcoach, little or no space would be left for the engine or passengers.

The real function of a motorcoach is to produce transportation that the public will support on a profitable basis. A successful transportation operation is one

[4] Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

that has a good gross income and low cost of operation. The part that instruments play is to keep down the cost of maintenance and operation. Can we select the proper group of instruments to analyze faults of operation in the minimum time, so as to save overhead and labor on mechanical troubles, personnel and route operations? Engine instruments help on mechanical troubles; recording on personnel and route operations.

Comparing motorcoach with railroad operations, we find that a railroad has a large number of instruments between the locomotive cab, dispatcher's tower and central station. Railroad instruments are scattered at three points; motorcoach operators have this combination all on the vehicle. We find the tendency is for the railroad operators to use more high-quality instruments. Motorcoach operators are not following the steps of the railroad operators, they buy low-priced instruments and do not get service or desired results. The paper is very timely, because we are now making a study of instrument applications on airplanes, locomotives and motorcoaches. I find for transportation purposes two definite points that must be accomplished, information and service at the minimum cost. Vibration, heat and neglect are the main sources of trouble on motorcoaches. In the past the slogan was, "Build instruments cheap and let them go out of service, then put in new ones." This policy is very expensive and costs more in the end than good high-quality equipment properly designed and applied.

Mr. Stocks has pointed out that recording devices are designed to facilitate operation and gives four divisions. To record such operations, a careful selection must be made from the available instruments and care used in application, if results are to be expected. Mechanical parts must be designed for proper lubrication or no lubrication except at long periods of inspection. We have found that, by elimination of mechanical drives, this point has been well taken care of. This means electrical devices in place of mechanical. Recording devices must be well damped and built to stand abuse and vibration. Where charts are used, care must be exercised to get the proper chart and pen or stylus, otherwise vibration will cause the pen to cut the chart. Various types of record are discussed by Mr. Stocks, but motorcoach operators must select the instruments, use them properly, apply them under the most favorable conditions and allow for deviations. Fig. 14 of the paper shows a speedometer with three scale sections. I do not agree with this dial, as too many things depend upon the operator, roads and traffic, and no one can determine safe or unsafe speeds, except the operator. The operator must be trained to judge conditions and the limits for top-speed travel on the highway. This points to a comparative fact between motorcoach and aviation operation. No one can drive an automobile, motorcoach or airplane by continually observing instruments, unless he is flying blind, and this experiment is still under way with the Guggenheim Foundation fund. To date blind operating is a dangerous experiment, whether it be on the groud or elsewhere. Therefore, the human eye must be used to drive a motorcoach and not to watch an instrument-board continually.

H. P. SPARKES

We have been successful in developing tachometers for locomotives, airplanes, automobiles and motorcoaches. The tachometer gives more information than simple road-speeds, and I would point to this as a possible means of saving in maintenance on engines, if operators are properly instructed that the engine should never exceed certain given marks on the dial, one for cold engines and one for normal. Then, when the transportation device is operated at other than normal-traffic speeds in lower gear-ratios, an appreciable saving on the engine will result if it is operated below the marked limit.

Instrument Standardization Urged

I would like to sum up the situation on automotive instruments, which have been considered a necessary evil. As a result they have been built for the minimum price and the result is very poor. Very little thought has been given to arranging the dashboard instruments and dashboards into a form suitable for standard motorcoach, airplane or any other form of transportation vehicle. A locomotive cab is simply a mess of steam gages, speed indicators and everything else mounted just where room could be found for them, and the motorcoach is the same way. I suggest that this Society designate a committee to standardize on motorcoach instruments of the heavier-duty type and see if the manufacturers will respond to the suggestions of this committee.

In making this suggestion as I have, I would like to offer my own personal opinion on this subject, and I hope that you will accept this opinion as a constructive suggestion so that I will not be misquoted. Some time ago, automotive ammeters were standardized, as to mounting dimensions, since drilling a hole in the dashboard was necessary. I imagine the same procedure took place on the speedometers and other equipment for dashboard use. Out of this grew the dashboard assembly such as is used on passenger-cars today. Should we not take a step farther in this type of construction and develop a motorcoach-dashboard unit? Let us assume that we have to place on the dashboard, in conjunction with the necessary switches and push-buttons, a speedometer, possibly containing one unit showing miles per hour and engine speeds and another showing trip miles; a device to show engine revolutions in the way of total counting; a start and stop counter; an oil-pressure gage; an ammeter; a suitable clock; a gasoline gage; a temperature indicator; and any other type of indicating apparatus suitable for analysis work. This might comprise the indicating bank. Not one of these units mentioned, except the ammeter, is so restricted that it could not be made electrical or mechanical. Each unit could then be turned in the vertical edgewise direction, similar to instruments I have seen mounted on the Hupmobile dashboard of today, except that these instruments will be closely grouped and much larger than the average 2-in. instrument, possibly a 3 or a 4-in. vertical edgewise-indicating instrument. These instruments would be arranged like pancakes stacked in a pile, then turned sidewise, set in under a curved glass cover, and the entire group assembly mounted directly

in front of the driver, giving him at one glance the entire condition of the vehicle he is operating. This type of assembly would be fitted into a case that would be mounted in a simple square hole cut in the dashboard, or set on a bracket and the entire assembly set in with indirect illumination behind the curved glass.

This assembly would accomplish two purposes. It would give a standardized motorcoach indicating-bank. The bank could be conveniently mounted in the dashboard, but if this bank had sufficient little push buttons and switches combined with it we could do away with the dashboard, which has no reason for existing, other than that the old carriage had one. Why not do away with the dashboard and go to designs that are somewhat similar to those used on some of the newer passenger-cars, where the dashboard is depressed or completely rolled away, with nothing but the steering column? Then the indicating-instrument group could be mounted in the bead where this particular finish sheet is applied to the cowling, that is mounted on the top edge. This would tend to give more footroom in the motorcoach.

Standardized single individual units for this bank could be designed interchangeably or possibly instrument elements could be standardized for all instruments with only a change in dial so that repair stock would carry one element with a set of dials so that we could make it read any operation desired. The above assembly would clear up the dashboard situation, standardize on elements and provide proper instruments for motorcoach operation.

With the indicating instruments cleared up, why not provide a space on each vehicle for a recording instrument to be placed in service in a standard box? Put these recording instruments out of the way where they do not look unsightly and under lock and key where they are only serviced by the proper authorities. Recording instruments are of all types, simple vibration-types, recording voltmeters adapted for various services and all this paraphernalia. Combine these into one unit and make one record.

From the manufacturing angle, I believe we would find the instrument manufacturers more than willing to cooperate with this movement. I think they would welcome a standardization of this type of apparatus and give all assistance.

We find power companies going more to triplex-dial instruments and banking them in composite groups so that any operator can tell at a glance what is going on in the system. Therefore, should not this class of application deserve the same analysis and study?

An approach to this proposition has been made by the White Co., of Cleveland, which is grouping this apparatus in a small box, neatly finishing it and trying to clear up the dashboard design. I believe all manufacturers should study the White method and see if they cannot take this idea and improve it and develop something for motorcoach service.

Yardstick for Measuring Instrument Performance

GEORGE S. ANDREWS[5]:—Before embarking upon the specific subject of operation instruments, may I offer a suggestion which I hope will be acted upon, as I feel that it is a constructive step. The motorcoach-transportation industry lacks a yardstick by which to judge the relative merits of instruments; this must handicap the operator when he is in the market for such equipment. The aviation industry has such a yardstick, and the Bureau of Standards applies it. Certainly the motorcoach industry has at least as great a need for some such standard. I suggest that, either through this Society or through some trade organization, the industry collaborate on this matter and establish a standard of performance and reliability that the various instruments must meet.

Any such equipment, to justify its presence on a modern motorcoach, should certainly be able to meet the following minimum requirements of reliability:

(1) Accuracy—2 per cent
(2) Calibration error—0.5 per cent throughout the scale
(3) Permanence of accuracy—no change from (2) after a continuous endurance run of 500 hr.
(4) Vibration and shock proof—500-hr. test to be made on the regular vibration board of the Bureau of Standards
(5) Effect of temperature change on accuracy—none
(6) Ratings for general excellence of design, materials, workmanship and sturdiness

No more suitable or competent or unbiased agency for the application of this yardstick could be desired than the Bureau of Standards. It has complete test equipment and skilled personnel. Leaving this thought with you, I will now proceed to discuss Mr. Stocks' paper.

Operators must acquire the frame of mind that all these instruments which have been discussed are mechanical and as such need periodical attention the same as other parts of the vehicle.

The attitude expressed by one prominent operator, that a speedometer which does not keep on working for 100,000 miles without any lubrication is not of much use, may be extreme. Nevertheless, it is indicative of a prevailing attitude that speedometers are expected to keep on grinding out high mileage without maintenance.

Perhaps we speedometer manufacturers are partly to blame, for even when the operator does right by the speedometer, it frequently does not do right by him. But assuredly the whole blame cannot be put on the manufacturer. The operator will not get his wish until he realizes that he has to pay for it. Operators may say that a great opportunity exists for some manufacturer to produce a speedometer that will be accurate and dependable. Is he prepared to pay for it? I would say, "No." Not all operators, by any means, accept the utility of the speedometer or of the odometer; they just add up the number of runs and multiply by the length of the routes and call it operated mileage. And I cannot blame them much. The indication of speeds to the driver, on a speedometer that he does not look at anyway, and a record of the mileage on the odometer which can be obtained closely enough from the number of runs and route lengths, is not enough information for the operator to justify the costs of maintaining speedometers and odometers. In my opinion, and I am a speedometer manufacturer, the conventional speedometer and mileage counter are on the thin edge of obsolescence insofar as the requirements of modern economic motorcoach operation control is concerned.

I think that the operator who realizes that much more needs to be known about what makes for coach and driver efficiency on the road than shows up in super-

[5] Sales department, R. W. Cramer Co., Inc., New York City.

visors' and drivers' reports will want what might be termed an automatic audit of coach operation and driver efficiency. He is not willing or able to do the volume of the clerical work connected with the present-day chart devices to get it. He wants the daily control ready-made for him but does not want to be swamped with numerous charts; he cannot handle them. Those chart instruments that really give all the phases of vehicle movement on the road are satisfactory for test work and an analysis of routes and schedules. But when that special work is done, the operator does not want to go through the same detail day after day. The charts have given him the standards to be set and then he needs some device that will tell him daily, and as automatically as possible, whether those standards are being maintained on the road.

The Telcam, which was illustrated in Fig. 11 of the paper, was designed to meet that need and to supply the operator with information on running and maximum speeds, how frequently and how long the vehicle was overspeeded, total running time, total mileage, average running-speed and layover and idle time. Among the advantages claimed for the device are entirely automatic operation, complete functioning, permanent accuracy, elimination of charts and combination of the function of the speedometer, odometer and speed governor, thus eliminating installation and maintenance costs for such accessories.

In its supervisory functions the Telcam is superior to road supervisors, for the latter can only supervise during actual contact with the vehicle and the cost of doing such work by man-power is excessive. Moreover, road supervisors' reports are inherently insufficient and involve too much of the human factor. It is also preferable to speed governors on the engine, in that it does not affect the extra margin of power occasionally needed to negotiate hills yet does record every case of overspeeding. The Telcam goes beyond merely taking the place of road supervisors. It gives automatically a daily audit of the basic operating-facts and enables the management to get the greatest efficiency and safety out of both man and machine, as operating conditions that tend to decrease these factors are shown up daily. The recording of overspeed or abuse factors enables the operator to suppress speeding and reduce accidents and maintenance costs due to the abusive handling of the motorcoach.

A. I. JOHNSON

Two forms are suggested for handling Telcam records. One is a driver's daily report form, on which each driver enters the readings shown on the dials when he goes on and off duty. Correct entries are assured by the fact that the relieving driver is personally interested in seeing that the man he is relieving has put down the actual readings. These data provide other derivative information, such as average running-speeds, schedule speeds, idle time and similar facts. The other form is a monthly operating summary for each vehicle. These data are collected from the drivers' daily Telcam reports and are more complete than can be obtained in any other way. The summaries tell at a glance the varying use and abuse on different vehicles and give an excellent and complete comparative picture of the demands made on various motorcoaches.

[6] Sales and engineering representative, Stewart-Warner Corp., Chicago.

Defense of Speedometer Dependability

A. I. JOHNSON[6]:—Several factors concerning the difficulty expressed by many motorcoach operators of keeping speedometers in operation were not brought out clearly in Mr. Stocks' paper and may be of considerable interest to operators. The difficulty in keeping this equipment in operation is primarily one of failing to specify equipment that is in any way adequate or was designed in any way for motorcoach use. Fully 80 per cent of the speedometer equipment on motorcoaches now in operation is of this type. If this light and inadequate private-car equipment were replaced entirely with such heavy-duty equipment as has been designed for motorcoach use and as has been available for several years and if it were scheduled for maintenance the same as other units of motorcoach equipment, the requirements for a speed-indicating and mileage-recording instrument would be solved in a very satisfactory manner for most operators. It is the equipment that will give the information most operators desire at the lowest initial cost, that can be maintained with the least expense and that has been proved by years of use and millions of miles of service to be the most reliable of any such device available.

Practically all of the large motorcoach manufacturers, with one notable exception, now use this equipment as standard. As operators have learned years ago in respect to all the essential units of motorcoach equipment, but which many have not learned in respect to speedometer equipment, the maintenance problem on this equipment must be given consideration in purchasing new vehicles. If this heavy-duty equipment is specified to be installed with a flexible shaft of reasonable length which is to be run in the most direct manner and in such a way that it will not be put out of proper operating-condition when work is necessary on the chassis, its maintenance is a negligible factor. In that connection, we speedometer manufacturers have to depend not only on the motorcoach manufacturer but also on the body builder. We make regular inspection trips to the various plants to see that installations are made according to our recommendations, but those recommendations are not always followed by the motorcoach and body builders.

Care in this respect is especially necessary where the body is built and installed by other than the manufacturer of the chassis. Under these conditions, the installation of the speedometer equipment has most frequently in the past received the minimum consideration. In this connection the Society should consider the practicability of proposing to all manufacturing companies and the operator the adoption of some standards for such equipment, especially the drives, which may be of assistance to both operators and manufacturers.

The majority of complaints on speedometer failures is entirely due to the lack of an understanding on the part of motorcoach operators as to modern equipment. If this equipment is properly maintained, it will give very satisfactory service.

F. C. HORNER[7]:—If we do not use these records intelligently after we have them, they will not be of any great use. Records of any kind always remind me of a doctor with a clinical thermometer. He can take my temperature and the thermometer tells him that it is normal, above normal or below normal. Then he has to apply the remedy. We have to use the records intelligently. We have to take advantage of what they tell us and be guided accordingly. If we do not, we might just as well not have the records.

I have operated motor-trucks and motorcoaches to some extent. I do not pretend to know much about actual operation, but I did operate trucks for a living once and it was not much of a living either. We have to take advantage of what our records tell us if we are to operate in a scientific and efficient manner. I do not think any operating man or anybody else will challenge that statement.

I agree with Mr. Sparkes that instrument standardization is a highly important subject, and I think that we should appoint a committee to study it. I will bring it up tonight at a meeting of the Transportation and Maintenance Professional Activity Committee and try to get something started along that line.

CHAIRMAN A. H. GOSSARD[8]:—We should have a motion made as to whether a committee should be appointed to work with the manufacturers, along the proper lines, to improve the location and the types of instrument.

ADRIAN HUGHES, JR.[9]:—The manufacturers' representatives, in discussing Mr. Stocks' paper, have shown us what they are trying to do in producing the instruments required. The important thing is for the manufacturers to know what the operators require, and the operators do not agree on that themselves. That point should be covered first.

I think that the suggestion of a committee is the only way we can get at it. So far the discussions of the manufacturers have been limited to their expressions from direct contact with a few operators, and they find that some instruments are not generally required or used. I move that a committee be appointed to approach that always difficult problem of having the operator tell the manufacturer what his requirements are. I would like to see some such contact arranged for.

MR. SPARKES:—Before we make a decision, I wish to bring out a fact that has been definitely established on motorcoaches around Pittsburgh. I have one man willing to pay as high as $75 for speedometers. He is buying and using them and getting around 150,000 to 200,000 miles with no maintenance.

I approached the White Co., in Cleveland, asking it to cooperate. J. E. Hacker, the experimental engineer, said, "If you can get the operators to standardize and say what they want, we will cooperate."

Now we have motorcoach operators willing to go ahead and we have the manufacturers willing to help. When we start this subject, we must realize that we are trying to set up a standard to compare with the other standards.

[7] M.S.A.E.—Assistant to the vice-president, General Motors Corp., New York City.

[8] M.S.A.E.—Manager of automotive and transportation department, Middle West Utilities Co., Chicago.

[9] M.S.A.E.—Superintendent of bus transportation, United Railways & Electric Co. of Baltimore.

[10] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark, N. J.

Province of the Proposed Committee

MR. ANDREWS:—When we talk of standards, do we include in that the suggestion I made as to performance? A standard of performance and reliability for each type of instrument is at least as important, if not more so, than shape or appearance.

MR. HORNER:—You will get the answer to that question from the operator. That is the acid test.

MR. ANDREWS:—This resolution, if acted upon, will eliminate considerable trial work that might be done by individual operators who have very definite knowledge of what they want. That knowledge is scattered and is not available to everybody else. It should be formulated into some definite standard to which all types should conform so that when the vendor submits his product, whether it be a new or old type, he has to meet the minimum requirements of those standards.

A. H. GOSSARD

MR. HORNER:—That is the purpose of forming such a committee.

MR. ANDREWS:—I just wanted to know if the proposed recommendation was to include standard of performance.

MR. HORNER:—I should say it ought to include every phase of the question.

CHAIRMAN GOSSARD:—This committee can only suggest that certain things be done; it cannot deal in standards or makes of instrument. My view of the matter would be that it can only make certain suggestions.

MR. SPARKES:—With the exception of the ammeter, every instrument on the dashboard of any vehicle can be made to operate mechanically or electrically. The Society has established a standard thread for bolts used on automotive apparatus, certain standards of rating engines and certain standards of tire sizes. If we are to provide a standard for measurement of operation, we must have the cooperation of manufacturers and operators. We do not care whether the instrument is mechanical or electrical but it must be a standard meter.

CHAIRMAN GOSSARD:—I still believe that the committee which is selected from this group can only suggest to the Standards Committee of the Society that certain standards be adopted.

MR. SPARKES:—If the men in this organization who are the buyers back the Standards Committee and require manufacturers to meet standards, the problem is solved.

Standard of Performance Ideal

J. F. WINCHESTER[10]:—A standard of performance would be ideal. We will always have with us the fellow who says he can make speedometers for $5 or $8 that will perform as well as one that costs $60 or $70. I have heard speakers here this morning who claim wonderful outstanding characteristics for some later product that costs considerably more. Yet, on the other hand, if we tear the models apart, we frequently find many of the parts in them apply to what was formerly used in the cheaper type of head. So where the differ-

ence in dollars and cents comes in is sometimes hard to determine. As a matter of fact, in our operation, we have bought expensive instruments and found that in time they did not stand up one bit better than the cheaper instrument. So I believe that a standard of performance is certainly an ideal thing to have.

I think one point that has been overlooked in the entire discussion this morning is the fundamental drive that has to do with operating the head. Personally, I believe that all flexible shaft drives at present operate at entirely too high speed. I believe we would have to go back to the point where the speedometer drive is taken off the transmission or the gear drive of the back of the transmission and analyze the matter from that point up into the speedometer head. In doing that, we find that if we can reduce the speed of the gears, the speed of the shaft and perhaps the speed of the mechanism within the head itself, we have a much better performing instrument than the majority in use today. That is fundamentally one of the great problems we have.

Mr. Stocks brings out this point and shows clearly what the average motorcoach looks like today. What the average operator wants today is a standard of performance so that when he buys an instrument he knows that he will get one which will stand up for a period of time.

MR. ABRELL:—Mr. Chairman, I would just like to call attention of the assembly to the fact brought out by the gentleman who just spoke, that in certain mileage instruments an attempt has been and is being made to reduce the revolutions of the driving shaft so as not to cause undue friction or undue wear on the gear parts. In most of our mileage-recording instruments, we fitted a gear-reduction box with a 16:1 gear ratio to the speedometer outlet of the transmission, driving our instruments 62 revolutions per mile.

ADRIAN HUGHES, JR.

CHAIRMAN GOSSARD:—The motion should be changed so that, if a committee is appointed, it would suggest to the Standards Committee that certain standards be adopted with reference to instruments and their performance.

MR. VIETS:—Will this committee mention trade names in their standards or will they merely standardize on the performance? I can imagine a standard thread but not a standard instrument being recommended by the committee.

MR. HUGHES:—The idea is to base the motion principally on the fact that before manufacturers know what to manufacture, they must know what the operators require. The important consideration of the committee is to determine what are the operators' requirements for the instruments, what they want to measure and what they need. Mr. Stocks will tell you that there is considerable room for discussion right there. A discussion of the relative value of various kinds of instrument is not pertinent at this particular time and can be postponed temporarily until the committee has tried to determine what the measuring instruments are or what must be measured by the operating companies. This committee will function like any other committee and will make certain recommendations regarding the requirements for measuring instruments for motor-coaches and motor-trucks and perhaps any other transportation instrument that enters into the picture.

CHAIRMAN GOSSARD:—The commitee, then, is to determine the requirements by working with the operators and the manufacturers.

MR. WINCHESTER:—I think it would be well to have Mr. Hughes restate his motion as he sees it.

MR. HUGHES:—That a committee be appointed to consider the requirements of operating companies for indicating and recording instruments. I think that covers the subject very broadly.

[The motion was carried.]

A Middleman Speaks

M. C. HORINE[11]:—I represent neither a manufacturer of instruments nor, in the main, a user of them. I represent a company occupying the unfortunate position of middleman which is faced with the problem of meeting the requirements of good instrumentation on the one hand and answering the price objections of an unappreciative public on the other. In other words, we must meet the service requirements of those who are dissatisfied with the best equipment which can be purchased and for which they are unwilling to pay an adequate price.

I have just one suggestion to offer the proposed committee that is to consider ideal instrumentation for a motor-truck. That is this: To expect the operator of a motor-vehicle to "fly blind," as it has been put here this morning, is out of all reason. Truck drivers do not watch their instruments. These instruments are installed principally to indicate abnormal conditions but are designed so that they show conditions as they are regardless of whether they are abnormal or normal. Why then, could we not produce instruments that will show abnormal conditions only and will make this positively evident to the driver when an abnormal condition exists?

One example, which can be multiplied by the number of kinds of instruments in common use, is the ammeter. That instrument indicates the ampere-rate of charge or discharge in the electrical system and is usually calibrated so that an accurate reading of the exact amperage is impossible. Furthermore, the driver would be unable to appreciate the exact reading of the ammeter even if he could obtain it. Consequently, he only watches whether the needle swings to the right or to the left. A simplification of the ammeter, therefore, would indicate merely the direction in which the current was flowing and not its rate. In other words, it would merely indicate a normal or abnormal condition.

MR. WINCHESTER:—When Mr. Horine says that the operators do not know what is going on when they see an ammeter register over 10 or 12 amp., he insults their intelligence. They know then that the battery is being overcharged; if they do not, they should not be at this meeting.

MR. HORINE:—Mr. Winchester, in his use of the term "operator," is referring to superintendents, engineers and managers of truck fleets such as are attending this meeting. My reference was to the driver of the vehicle,

[11] M.S.A.E.—Sales promotion manager, International Motor Co., Long Island City, N. Y.

none of whom, so far as I know, are in attendance here. I am sure that he will agree with me that even though an ammeter did correctly record the fact that the generator started charging at speeds above 600 r.p.m. and reached a maximum of 11.5 amp. at 1800 r.p.m. and that throwing on a full lamp-load caused a discharge of 4 amp. at 1200 r.p.m. would be of very little practical guidance to a motor-truck driver. About the only report drivers make on ammeter readings is in cases where the generator clearly is not charging or where the ammeter fails to register.

A. J. SCAIFE

Instruments Should Force Driver To Be Careful

PAUL P. PIERCE[12]:—I have listened to this discussion with considerable interest. All the instruments in question deal with safety either to the man operating the motor-truck or motorcoach or to the vehicle. We need an integrating instrument, not to indicate to the driver what he is going to do or what the vehicle can do but to make him do it. If we cannot make him do it, then make the engine do it.

I am thinking, particularly—although I know of no such instrument on the market today—of a motorcoach rounding a curve at 45 m.p.h. when it ought to be going at 20. An instrument can be developed which will automatically control the speed of the motorcoach and the feed of gasoline to the engine so that the operator cannot drive any faster than he should around the curve.

This might be a very complicated instrument, but it might go a long way toward solving our problem. The instrument should not only indicate, but something should happen to make the driver take some action or else not leave it to his judgment.

MR. SPARKES:—That is the same as the automatic train-control on the railroads. Today a locomotive approaches a caution signal and with a continuous-current system the speed is reduced sufficiently for the requirements of safety. Through the growth of that particular development, a company today is experimenting with a device that will automatically stabilize an airplane. The pilot can be asleep and the plane will fly a true course. Additional developments for motorcoach control may come later, whereby the operator can have the throttle wide open but the speed is reduced automatically if the vehicle exceeds a certain rate on a curve.

In answer to Mr. Horine's point, I would like to call attention to the miniature dashboard shown in Fig. 2. The White Co. has installed an ammeter on this board for determining leaky grounds and small faults if all switches are off. The needle should be on zero, if the ammeter is a good instrument. In addition, a trouble light is provided, which lights immediately if any large undue faults occur in the electrical system.

[12] M.S.A.E.—Engineer, engine division, refined oil department, Vacuum Oil Co., New York City.

[13] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

[14] M.S.A.E.—Treasurer, Karnak Chemical Co., West Chester, Pa.

Tachometer or Speedometer

ARTHUR J. SCAIFE[13]:—I would like the committee to consider the tachometer as an indicator to determine engine life and to see what the operators think about it as a definite yardstick for measuring distance instead of miles. The use of an odometer for calculating miles as a basis for engine life is satisfactory where all the vehicles are uniform as to gear ratios, and this was particularly true in the past when motor-trucks were operating with solid tires and slow speeds with very closely confined gear ratios. Now that we are running from 40 to 60 m.p.h. with motorcoaches having gear ratios of between 4 and 5 to 1 and weighing between 20,000 and 30,000 lb. gross, using the road mile as a measuring stick for engine life and also using this same engine in a motor-truck train having an operating speed of from 20 to 30 m.p.h. and carrying gross loads of between 70,000 and 90,000 lb. with gear ratios that are very widespread is very difficult.

If we base the life of a motorcoach unit at 150,000 miles, we could not expect the units in a motor-truck to give the same mileage, as the units do practically three times the amount of work in a motor-truck in covering the same number of miles. Therefore the life of the engine should be based on engine miles instead of vehicle miles.

JOHN S. BLEECKER[14]:—The suggestion has been made that perhaps the motorcoach driver should not have a speedometer because he does not look at it. When we take the speedometers off the motorcycle officers' motorcycles, it will be time enough to remove them from motorcoaches but not before.

MR. WINCHESTER:—Is the tachometer that Mr. Scaife advocates any more reliable than the speedometer?

MR. SCAIFE:—I hope that if they make tachometers, one will be as reliable as the other.

MR. PIERCE:—When the tachometer is put on, I hope that it will show at what speed the engine should run to do its work properly.

FIG. 2—AN EXAMPLE OF INSTRUMENT GROUPING USED BY THE WHITE MOTOR CO.

The Jewel Lamp to the Left of and below the Ammeter Is Green and Indicates Whether or Not the Tail-Lamp Is Burning, the Clear Jewel Lamp at the Bottom of the Board between the Ignition and Choke Controls Indicates an Overload, and the Red Jewel Lamp to the Right of and below the Oil-Pressure Gage Indicates Whether the Stop Light Burns When Pressure Is Applied to the Brake Pedal

MR. WINCHESTER:—I was not impressed with the odometer with the drive taken off the oil pump as shown in Fig. 20. In very many territories the instrument would be knocked off in short order. As far as the tachometer drive is concerned, it appears to be a very poor one. We could not rely on instruments that have drives of the type shown.

MR. SPARKES:—That installation ran 150,000 miles without having a screw-driver on it.

MR. SCAIFE:—While we are giving this subject consideration, the tachometer should also be considered, as no provision is made at present for its use. A place can be provided on the engine base for its attachment should the demand arise which is the point that I have in mind.

MR. ANDREWS:—Did the tachometer have the same accuracy at the finish as when it started? In other words, at 1600 r.p.m. of the engine did the tachometer indicate 1600 at the end of the 150,000 miles? If it did not, then its indication does not mean very much.

MR. SPARKES:—On the original test as placed on the car the tachometer showed, like all tachometers, an accuracy of ¼ per cent. The accuracy is still within the limits of ½ per cent.

How Valuable Are Instruments?

R. H. VAN NESS[15]:—We are operating 250 units on route work for commercial delivery, and use speedometers as instruments to collect daily-mileage readings on which to base direct operation-costs and only use the recording instruments when making surveys and time studies.

I would like to know if any one operating under the same conditions has ever weighed the value of the recording instruments when using them as standard equipment in place of speedometers. My reason for asking this is because this matter has been brought up as being of considerable value. Therefore, I would like to know the value in dollars and cents which can be obtained by using recording instruments to justify the investment and maintenance of same.

CHAIRMAN GOSSARD:—Perhaps the committee can include that in its report.

L. V. NEWTON[16]:—The importance of fine instruments for use on passenger-cars and motor-trucks, such as ammeters, oil-pressure gages, heat indicators and the like, has been over-estimated. To even presume that such instruments should be, through necessity, of as high quality as those used on aircraft is ridiculous. Some one present stated that some modern passenger-cars or motor-trucks were equipped with ammeters that cost the vehicle manufacturer 19 cents. If these instruments cause us no trouble, what difference does it make how little they cost the car manufacturer? Considering the volume in which such instruments are produced, the cost to the vehicle manufacturer is not, I believe, an index of quality.

We, like all other large operators, have difficulty in keeping speedometers in working order. My belief is that this will continue to be true until speedometers are designed with a lower shaft-speed. Recordografs and recording instruments are of great value. I do not advocate putting one of these instruments on each motor-truck, in fact I have found that, by having a few Recordografs on hand, they can be satisfactorily shifted from one vehicle to another, and the desired data accumulated.

An important field of usefulness of the Recordograf which has not been mentioned is determining those trucks on which engines are permitted to idle unnecessarily. A hazy line is shown on the chart during the idling period in contrast to the heavy marks made on the chart during the time the truck is traveling.

H. B. HEWITT[17]:—Our experience is, in general, just about what has been discussed this morning. Increasing the load factor of the vehicles, which is a very important item for the consideration of the operators, is one item that would prove the value of recording instruments. We had a study made which enabled us to fit in chartered school motorcoaches with the regular runs and left about five vehicles free for other purposes. We do not undertake to maintain speedometers except in States where the Public Service Commission requires them to be used.

JOSEPH ZUBATY

CLIFFORD TURNER[18]:—Both the tachometer and the speedometer leave something to be desired when used individually, and I would suggest a composite speedometer and tachometer. The tachometer unit could be driven from the front of the transmission and the speedometer unit could be driven from the rear of the transmission with a concentric or an adjacent guide for recording purposes so that the driver would have it visible to him. This instrument could also be adapted for recording purposes.

Motorcoach and Passenger-Car Speedometers Compared

JOSEPH ZUBATY[19]:—According to the paper, speedometer installations on passenger-cars differ greatly from those on commercial vehicles in general and motorcoaches in particular. This difference is primarily in the definition of satisfactory service in each group.

The problem of satisfactory installation on passenger-cars was solved very many years ago, and the engineering efforts in the last 3 or 4 years have been directed to decreasing the cost of installation, while maintaining the same standard of performance. On passenger-cars no attempt is made to service and repair or lubricate the speedometer equipment. As a matter of fact, both units, speedometer head and flexible shaft, are made so that they cannot be disassembled or relubricated without special equipment that is available only at authorized service-stations. The speedometer equipment designed and developed for passenger-car purposes met both laboratory and road tests of 50,000 miles with full satisfaction. Individual tests were made at the laboratory wherein speedometers were operated successfully without any relubrication or other attention up to 250,000 miles.

[15] A.S.A.E.—Superintendent of transportation, City Ice Co. of Kansas City, Kansas City, Mo.

[16] M.S.A.E.—Automotive engineer, Byllesby Engineering & Management Corp., Chicago.

[17] Engineering assistant to vice-president in charge of operation, Mitten Management, Philadelphia.

[18] Manager, Inter City Transport & Motor Co., Buckhannon, W. Va.

[19] M.S.A.E.—Chief engineer, A. C. Spark Plug Co., Flint, Mich.

However, on motorcoaches and motor-trucks, the problem seemingly differs from that on passenger-cars, and therefore a new solution must be found to meet a new condition. First of all, original ownership of a motorcoach probably covers a period of 5 years and up to 500,000 or more miles, a length of service that no accessory containing moving parts can withstand without attention. This includes the major units of the vehicle, such as engine, transmission and rear axle, as well as ignition, lighting and speedometer equipment. Therefore the first problem will be to divide this length of life into suitable periods at which the speedometer equipment should be thoroughly serviced. We believe that if the installation is correct—and this pertains primarily to the flexible shaft, its length, number of bends and radii of these bends—nothing is hard or unusual about motorcoach service as compared to passenger-cars. We believe that the suspension of motorcoaches is entirely adequate and also that modern engines now in use compare favorably with passenger-cars as to vibration. Therefore, the same length of life as obtained on passenger-cars would seem to apply to motorcoaches, that is, approximately 50,000 miles.

The success of a motorcoach installation undoubtedly lies in the proper installation of the flexible shaft. The first difficulty is that the shafts are very much longer than those used on passenger-cars. We very seldom find shaft lengths over 5 ft. on the latter, whereas motorcoach installations run as high as 20 ft. or over. Internal friction of the flexible cable in the flexible housing adds so much load on the lower driving-end of the cable that it materially decreases the cable life and also adds to the possibility of breakage in case of frozen grease or sharp kinks in the installation. The only way to make these 20-ft. shafts perform is to use stronger and heavier flexible cables, but again this has a disadvantage due to their stiffness. In other words, the longer the flexible shaft, the stiffer it has to be, therefore we must avoid sharp bends and make all radii as large as possible. The 8-in. radius mentioned in the paper should certainly be the minimum.

The so-called speed adapters are another source of trouble in speedometer installations on motorcoaches. As is the case with passenger-cars, several standard transmission-units are available for motorcoaches, and manufacturers consider using these standard units without consideration of the final rear-axle ratio and tire size, an advantage. Inasmuch as the speedometer take-off is built into the transmission, its speed must be corrected to obtain true speed and mileage readings with the various gear-ratios used in the rear axle and also various tire-sizes that can be mounted on the final product. Inasmuch as changing the gear in the transmission itself would be rather expensive, using the so-called speed adapters, which are mounted between the transmission and flexible shaft, to correct the speed to the right value is considered an advantage. These speed adapters are small housings containing either spiral or spur gears and are designed so that the gear ratio can be varied by selecting the correct gearset. These adapters are designed so that one side fits on the transmission speedometer take-off while the other is connected to the lower end of the flexible shaft. Nothing is wrong with the principle of this installation; but the space available for the adapter installation is limited, and, therefore, all the parts are extremely undersized which, in turn, causes failures. Passenger-car manufacturers long ago abandoned this idea and introduced several gear-ratios built directly into the transmission so that the transmission has to be matched with rear axles. If this solution is not practical or economical in the motorcoach field, the transmission manufacturer should design an easily accessible variable-gear adapter directly into the transmission housing. A design of this kind was in actual use some years ago on Cadillac cars and was entirely satisfactory, although somewhat more expensive than matched transmissions as used today.

I have endeavored to point out just a few items that must be taken into consideration in designing satisfactory speedometer-equipment for motorcoaches. To cover the subject fully would be impossible, because many points still remain to be discovered and worked out by the motorcoach and the speedometer-equipment designer. In this connection, we must appreciate the splendid cooperation that existed between passenger-car engineers and speedometer manufacturers in developing satisfactory equipment and sincerely hope that closer cooperation will exist in the future in the commercial-vehicle field as well.

Remedying Speedometer Failures

To make some progress we need facts and figures about speedometer failures on motorcoaches. We need to know the make of equipment, how many failures occurred out of total instruments used, mileage at point of failure and whether speedometer head or shaft failed. We also need to examine the parts that failed. So far we have definitely found that dissatisfaction with speedometer equipment on motorcoaches exists, but we have no data on hand which would enable us to begin correcting this situation. One operator in Mr. Stocks's paper complains about equipment breaking down in less than 1000 miles, while another admits that present equipment would run in the neighborhood of 20,000 miles if properly installed and maintained. This is brought out, not as a matter of argument, but just to illustrate that we will have to get together and understand each other.

As stated previously, the total required life of speedometer equipment should be divided into definite periods, at which the equipment should be cleaned and lubricated. I feel safe in saying that the speed indicator itself will withstand 50,000 miles of any service without attention. However, after this mileage it should be disassembled to the extent of permitting relubrication of internal working-parts. In doing this, extreme precaution must be taken not to damage delicate internal mechanisms and certain specified lubricants must be used to get satisfactory results. Years have been spent to develop proper lubricants and also correct quantities to be used in each place. On passenger-cars we handle these overhauling operations through authorized service-stations that have equipment and instructions to do them correctly. Motorcoach operators must do the same or else provide equipment to handle this work themselves. We have no objection to releasing the necessary information and tools for maintenance to any of our customers, but to do those things successfully really requires considerable education and skilled help. Therefore, we believe that this subject will have to be discussed further before any recommendation is made. We are prepared to facilitate shaft lubrication by placing a standard pressure-lubrication-gun attachment on the flexible shaft, preferably somewhere in the middle of its length. This opera-

tion can be included in the regular lubricating-schedule, and we believe that it should not be necessary oftener than once in every 5000 miles. This period may be shorter if preferred, but precaution must be taken not to force the lubricant into the speed-indicating head. The flexible cable must be detached from the head during this lubrication operation.

Substitution of Engine Tachometer for Speedometer

Mr. Stocks's suggestion of using an engine tachometer for speed indication and that the suggested total-revolution counter be used as a basis of motorcoach service in place of mileage is welcomed. The company with which I am connected does not manufacture electric tachometers as advocated in the paper but several years ago placed on the market a magnetic tachometer that has since become almost universally used on motorboats and racing cars. The main advantage of using a

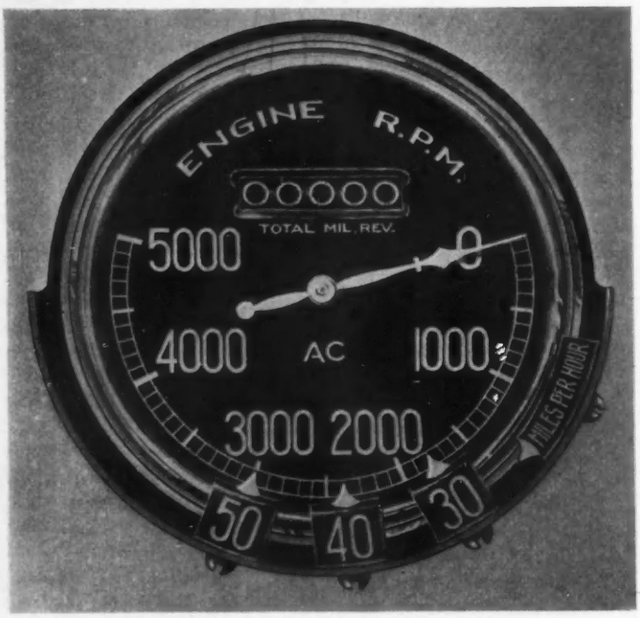


FIG. 3—POINTER-TYPE ENGINE TACHOMETER THAT ALSO SERVES AS A SPEEDOMETER

The Number of Engine Revolutions per Minute Is Indicated by the Movement of the Pointer along the Graduated Arc and the Total Number of Revolutions, Which Serves as a Basis for Maintenance Work, Is Registered by the Figures at the Top. The Actual Vehicle-Speed Is Indicated by the Adjustable Marks Which Are Moved To Compensate for the Rear-Axle Gear-Ratio and the Tire Size of the Vehicle on Which It Is Installed

tachometer that is driven from the engine is that the flexible-shaft installation will be very much shorter than on the present speedometers and also the speed of rotation of the shaft can be reduced, thus lengthening its life very substantially.

An S.A.E. Standard for Engine-Tachometer Take-Off on airplane and motorboat engines was adopted some years ago[20]. As a matter of fact, several manufacturers of engines have adopted this take-off on their product because a demand for it existed among their customers. To assure the most satisfactory length of life of the flexible driving-shaft, the tachometer shaft should make one revolution for each four of the engine crankshaft. Due to positive mechanical connection between the engine and the tachometer head, incorporating the total-revolution counter will be very easy and the appearance of the instrument will be very much like the pointer-type speedometer recently introduced by the leading automobile manufacturers. While the indication of revolutions per minute will be correct on any installation, provided the tachometer is calibrated to the correct speed of the take-off, the reading of the vehicle speeds in miles per hour will have to take into consideration the rear-axle ratio and tire size. One possibility would be to place before the driver, on the dash, a chart calculated for the conditions of his vehicle and giving the relation between engine revolutions and vehicle speed in all gears. Still another and preferred way of obtaining this is by placing adjustable marks on the outside rim of the instrument indicating actual speed, such as 30, 40 or 50 m.p.h. Fig. 3 illustrates the appearance of this instrument, which, if it is correctly installed and the flexible shaft is periodically lubricated and indicator is inspected and oiled every 250,000,000 revolutions, would be a very satisfactory motorcoach speed-indicator.

In working out the engine-tachometer installations, several rules must be observed the same as applied to speedometer-transmission drives. In addition to keeping the flexible shaft as free from sharp bends as possible, we must also see that the flexible shaft is not in contact with the exhaust manifold, because that would cause overheating, lost lubricant and shaft life.

Test Instruments Compared with Regular Installations

JOSEPH HUSSON[21]:—Will some of the operators who are here and use recording instruments tell me what is the value of those instruments for test purposes where the instruments are transferred from one vehicle to another, as compared with equipping all the vehicles in a fleet with the instruments? We have been approached many times on the subject of purchasing such recording instruments to increase our truck efficiency. The procedure followed is to buy one or two and try them out on some routes where we feel that we are not obtaining the results that we should. Then the vendors keep coming around and asking us to put these devices, which apparently are good, on all of our trucks. What I would like to know is whether any man in this room has had that particular problem, how he solved it and with what instruments?

MR. WINCHESTER:—I may not answer the question exactly but I will give you the benefit of the experience that we had. On all of our equipment we use speedometers with the idea in mind of furnishing a check so that the inspector can set the governor properly. Speedometers act not only as a help to him but also assist in keeping the truck speed within the operating limits that we set, and also serve as a mileage record upon which our operating costs are based. Some people have said at times that operating records based on mileage were not accurate, but we honestly attempt to keep the speedometers in operating condition and have them functioning properly.

The simple recording device that was shown here this morning is one that we have used. We have always used instruments of that type and we have not only used that type but also one or two of the others that

[20] See S.A.E. HANDBOOK, 1930 edition, p. 14, for the aeronautic-engine take-off. That for motorboat engines, which is the former aeronautic standard and of heavier construction, is now in process of revision by the Motorboat and Marine-engine Division of the Standards Committee.]

[21] Transportation engineer, Vacuum Oil Co., New York City.

were shown, particularly the Pittsburgh recording device which punched the ticket. We found that to be particularly good because at times a necessity has arisen for more than one department to have a record. The route foreman who was operating the trucks had the record available immediately and could send another through to the office where, perhaps, the supervisor wanted to look it over. We have pursued the policy of installing that type of instrument on a vehicle, testing out the route, setting the work for the driver. After that basis was established, we shifted the instrument to another vehicle and followed the same procedure.

MR. HUSSON:—That partly answers my question. I am looking for an operator who has equipped his fleet with one of these various types of device and can tell me why he did it and what the net result was.

T. W. NOONAN[22]:—We are using the so-called Hassler recorder which gives us a record in graph form. We use it in compiling route schedules to determine the running time, the time between points on a line and the maximum speed allowable for the operators. We have been approached, just as Mr. Husson states, to equip our whole fleet. We have never done that, because we felt that the investment would be greater than would be justified by the results.

T. W. NOONAN

We have moved the instruments from one vehicle to another or we have moved the motorcoach from one line to another. We have been able to check up on the complaints that we have received from our operators that the schedule was too fast or too slow for the running time from one point to another. That helps us, also, in scheduling our runs. When we make up a schedule we know that we are within the requirements of the State law of Pennsylvania, which has a maximum speed of 35 m.p.h. We develop our schedules on a 30-m.p.h. maximum to give a 5-mile allowance to keep our operators out of the hands of the law.

H. D. HUKILL[23]—Mr. Stocks's paper makes no mention of the brake-application counter. This instrument, while not required in standardized operations, is of considerable value for complete records on brake-lining and brake-drum-life investigations or brake-maintenance costs.

Car mileage as an ordinary measure for brake-lining and brake-drum life may lead to erroneous conclusions from comparative records, when other factors are not taken into consideration. The actual duty or service imposed on these parts is measured by the total number of stops multiplied by the total energy per stop. While certain of the recording instruments described provide sufficient data, indication for each stop and initial speed from which the stop was made, evaluating the total work done by a set of brake-linings would be a very laborious task indeed when we consider that the total number of stops during the life of a given set of linings may run into hundreds of thousands. For ordinary comparisons or life records, number of stops only is considered, but care must be used in interpreting such results, since in making a stop from 40 m.p.h. the brakes are called upon to do 16 times as much work as in making a stop from 10 m.p.h. This means, of course, that proportionately less lining life will be obtained where high-speed stops are involved.

On the other hand, the number of stops per mile varies greatly in different classes of service. In strictly city-service runs through rush hours, the average may be as high as 12 stops per mile, while other motorcoaches on cross-country runs may not show up more than 1 per mile. In making any comparison of brake-linings or brake-drums, a record of the number of stops is of considerable value as, with due allowance for speed and brake size in comparison with vehicle weights, such figures are a much truer measure than mileage only. A very simple stop-recording device consists of installing a Veeder counter under the hood or beneath the dashboard with a spring connection to the brake pedal.

CHAIRMAN GOSSARD:—Just as motion studies in industry lead to lower cost and greater productivity, movement studies of motor-vehicles will lead to lower cost and more revenue or work performed. If operation of motor-vehicles is to become a science, it needs measuring instruments that are accurate and reliable.

[22] General manager, Pittsburgh Motorcoach Co., Pittsburgh.

[23] M.S.A.E.—Manager of power-brake division, Bendix Brake Co., South Bend, Ind.

Tires and the Rim-Riddle

(*Concluded from p.* 344)

We forget that experience proves some of our worst fears groundless. We forget that trends are perhaps the outstanding fact of present-day industrial-life. We forget that, when rightfully interpreted, trends point to the need of keeping up to the minute in our knowledge of current changes. We forget that the trend toward wire wheels may not be increased or even maintained by its present momentum, and that the rate and direction may be changed suddenly to a wood or a disc wheel with drop-center or some other kind of rim. We forget everything except to post a sharp lookout to try to discover when a slow-down of one trend sets in and an acceleration of another begins.

There are objectionable features to the drop-center rim and tire program, which we who play with it carelessly will discover. The tire-and-rim riddle that has kept us guessing for a third of a century has not by any means reached its solution. Yet we cannot close our minds to the facts that upward of 60 million tires on cars equipped with drop-center rims have rendered a performance that has been highly acceptable to a class of American motorists who evaluate rims and tires by the service and safety they render, as well as by the ease of their application and removal. Therefore, for small cars, the drop-center rim appears to be a step in advance and, hence, a success.

Torque, Thrust and Power for Drilling

By O. W. Boston[1] and C. J. Oxford[2]

Annual Meeting Paper

TESTS on drilling various grades of steel and cast iron were conducted in a specially equipped drill-press at the University of Michigan and reported in detail in a previous paper. The present paper is an extension of the results of these tests in formulas, tables and charts for determining the thrust, torque and horsepower that will be required in practice for drilling with drills of 1½-in. or smaller diameter in the various materials that were tested, which were representative of those commonly used in industry.

THE object of this paper is to present, for practical and convenient use, data resulting from tests in drilling specimens of 17 different steels and 1 cast iron. These data—relating to torque, thrust and power developed by drills ranging from ½ to 1½ in. in diameter—have been reported previously in detail by us in an earlier paper[3], and are here represented by empirical formulas, tables and charts.

The drills used in these experiments were furnished by the National Twist Drill & Tool Co., and were selected as being representative of drills corresponding with its standard specifications for taper-shank, high-speed-steel twist drills. They were furnished in sizes of ½, ⅝, ¾, 1, 1¼ and 1½-in. diameter. Each size was furnished in duplicate, one stamped R and the other stamped L, for purposes of identification. The drills were ground in an SPK Blau drill-grinder with the overhang of the drill from the jaws set by a gage, and varying according to the diameter of the drill, as listed in the last column of Table 1.

The head of the machine was also carefully set to the correct drill diameter so that, with the overhang specified, the drill could be reground without changing the various drill-point angles.

The grinder forms the drill point so that it has a conical surface back of the cutting edge. The drills were measured after each grinding on a special measuring instrument which employs a dial gage, with its spindle parallel to the axis of the drill but off center, to make sure that the cutting edges at the periphery were advanced to the same relative position or lead to cut chips of equal thickness. Newly sharpened drills were again reground if one lip was in advance of the other by more than 0.001 in. This precaution was taken to eliminate any influence on the test results from any chip thickness other than that desired. If, for instance, a 1-in. drill had a variation in lead of one cutting edge over the other of 0.005 in., which is not uncommon in drill grinding, and the drill was being fed into the material at the rate of 0.013 in. per revolution, the advanced cutting edge would remove 0.0115 in. of material per revolution while the lagging cutting edge would remove only 0.0015 in. Inasmuch as thick chips are removed more efficiently than thin chips—that is, with less power per cubic inch of metal removed per minute—the resultant torque and thrust in the case of uneven chip thickness might not equal those for a correctly ground drill.

Table 1 contains a list of the drills used in the tests, and gives the values of various measurements, such as the outside diameter, the web thickness at the point after the first grind and again after being ground at the conclusion of the tests, the chisel-edge angle or the angle the chisel edge makes with a cutting edge, and the helix angle of the land measured at the point and at the shank. The included point-angle between the two cutting edges was 121 deg. in all cases. The clearance angle ground back of the cutting edges at the periphery is shown for each R drill in Table 2.

Symbols Used in This Paper

B = thrust on drill, pounds
C = constant in torque formulas
d = diameter of drill, inches
f = feed of drill, inches per revolution
hp = total net horsepower at drill point
hp_b = net thrust horsepower
hp_t = net torque horsepower at drill point
K = constant in thrust formulas
N = drill speed, in revolutions per minute
P = penetration of drill, inches per minute
T = torque of drill, pound-feet
V = volume of metal removed per minute, cubic inches

Subscript numbers or letters, like 6150 or *ci*, distinguish values for the specific materials indicated.

[1] Professor, college of engineering, University of Michigan, Ann Arbor, Mich.

[2] Chief engineer, National Twist Drill & Tool Co., Detroit.

[3] See *Transactions of the American Society of Mechanical Engineers*, Machine Shop Practice Division, vol. 52, No. 3, 1930, paper MSP-52-2.

TABLE 1—DIMENSIONS OF DRILLS USED IN TESTS

Drill Size, In., and Mark	Outside Diameter at Point, In.	Web Thickness at Point, After First and Last Grind, In.	Chisel-Edge Angle, Deg.-Min.	Helix Angle at End		Overhang in Grinder, In.
				Point, Deg.-Min.	Shank, Deg.-Min	
1/2 R	0.4990	0.0792—0.083	129— 0	29— 0	27—45	0.275
1/2 L	0.4988	0.0805	130— 0	29—20	24—30	
5/8 R	0.6242	0.0943—0.0945	129— 0	32— 0	31— 0	0.300
5/8 L	0.6244	0.0894—0.0910	131— 0	31—55	29— 0	
3/4 R	0.7494	0.1071—0.1072	134— 0	31—10	28—30	0.325
3/4 L	0.7493	0.1110—0.1115	134— 0	30—55	28—10	
1 R	0.9989	0.1346—0.1395	136—30	31—15	28—10	0.375
1 L	0.9990	0.1340—0.1495	136— 0	30—55	27—55	
1 1/4 R	1.2500	0.1580—0.1730	138—30	30—10	28— 5	0.425
1 1/4 L	1.2490	0.1595—0.1675	139— 0	31— 0	27— 0	
1 1/2 R	1.5000	0.1845—0.2135	138— 0	31—20	29— 0	0.475
1 1/2 L	1.5000	0.1873—0.2140	135— 0	31—30	29—15	

The Materials Drilled

The materials drilled in these experiments consisted of 17 steels and 1 cast iron. The steels were obtained in bars 2 in. wide by 4 in. deep and from 14 to 20 in. long. They were selected to represent a number of the steels more commonly used in industry. All materials are listed in Table 3. The steel bars are numbered from 1 to 16, inclusive, and 19, while bar 18 is cast iron, also 2 in. wide by 4 in. deep, and 4 ft. long, as cast in the University foundry. The chemical analyses of several of the bars are given in Table 4.

TABLE 2—CLEARANCE ANGLES OF DRILLS, AS REQUIRED BY FEED AND ACTUAL

Drill Size, In., and Mark	Width of Chisel Point, In.	Practical Feed, In. Per Revolution	Feed Helix		Clearance at Periphery as Ground, Deg.-Min.
			At Periphery, Min.	At Chisel Edge, Deg.-Min.	
1/2 R	0.115	0.009	20	1—25	5—20
5/8 R	0.150	0.011	19	1—21	5— 0
3/4 R	0.160	0.012	17	1—19	4—40
1 R	0.205	0.013	14	1—10	5— 0
1 1/4 R	0.235	0.015	13	1— 9	5— 0
1 1/2 R	0.250	0.015	10	1— 5	5— 0

The steels were given a heat-treatment at the mill, to provide a grain structure and degree of hardness which was thought suitable for machining purposes. These heat-treatments are indicated in Table 3.

The surface, 1/4 in. in depth, was milled off the edge of each bar at the end so as to present a surface about 2 in. square. These surfaces were then filed smooth, after which hardness tests were made on them. The Brinell, Rockwell B scale, and scleroscope hardness numbers also for each bar are given in Table 3.

Recommended Speeds and Feeds

Table 5 shows the speeds and feeds recommended by the National Twist Drill & Tool Co. for drills ranging in diameter from 1/16 to 2 in., working in various materials. The feed per revolution for each size of drill is shown opposite the drill diameter. The recommended peripheral speed in feet per minute for high-speed-steel drills is indicated under the name of each material, and the revolutions per minute for each drill size and each material is given in the body of the table. The same information is shown graphically in Fig. 1, in which the drill diameters are shown at the left, with the corresponding feeds indicated at the right. The relations between the peripheral cutting speeds in feet per minute, as shown at the bottom of the chart, and the revolutions per minute for each size of drill are shown by the lines radiating from the lower left-hand corner. For instance, interpolation shows that the rotational speed of a 1-in. drill is approximately 380 r.p.m. to give a peripheral speed of 100 ft. per min.

TABLE 3—TYPE AND HARDNESS OF MATERIALS USED IN DRILLING TESTS

Bar No.	Material, S.A.E. No.	Heat-Treatment, Deg. Fahr.			Brinell No.	Rockwell B Scale	Scleroscope No.
		Normalize	Anneal	Reanneal			
1	1020	....	....	....	137	84	29
2	1045	1600	1475	....	159	82	28
3	2320	....	1600	....	163	85.5	25
4	3120	....	1600	....	143	75	24
5	3135	1575	1500	....	192	88.5	29
6	6150	1650	1550	....	187	86.5	29
7	3250	1650	1475	....	207	92.5	30
8	3140	1650	1500	....	196	92	30
9	2330	....	1500	1400	202	93.3	32
10	2340	....	1500	1400	207	93.5	32
11	6120	....	1500	1400	137	76.5	25
12	6130	....	1500	1400	156	81.5	28
13	6140	....	1500	1400	163	85.5	28
14	9250	....	1500	1400	202	93	32
15	CrMo	....	1500	1400	156	77.5	27
16	CrMo	....	1500	1400	156	79	27
19	1095	....	Yes	....	154	85	25
18	Cast Iron		As Cast		163	83	32

TABLE 4—CHEMICAL ANALYSES OF TEST BARS,[a] PER CENT

Bar No.	6	7	8	15	16
Carbon	0.50	0.50	0.50	0.33	0.28
Chromium	0.80	1.00	0.60	0.66	0.65
Nickel	...	1.75	1.25	...	...
Vanadium	0.20	...	...	...	...
Silicon	...	...	...	0.20	0.23
Manganese	0.20	...	...	0.50	0.52
Molybdenum	...	...	...	0.18	0.19
Phosphorus	...	...	...	0.011	0.028
Sulphur	...	...	...	0.010	0.017

[a] Other steel bars were of commercial analysis.

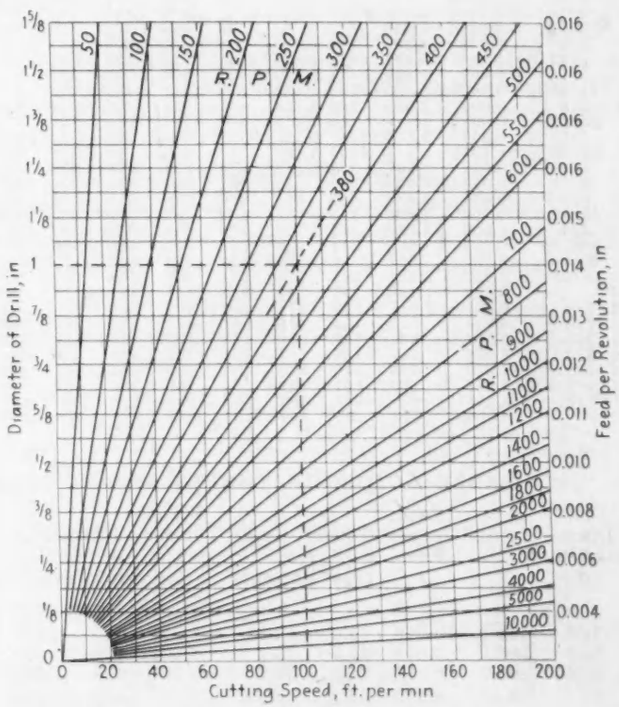


FIG. 1—SPEED AND FEED CHART FOR DRILLS

The drill penetration per minute, P, is equal to the feed per revolution, f, times the speed of the drill, N, in revolutions per minute

$$P = fN \qquad (1)$$

Torque and Thrust

Commercial Data.—The values of torque, thrust and power were determined, as shown in the upper part of Table 6, from drilling tests on bar No. 6, of S.A.E.

6150 chrome-vanadium steel, under various commercial conditions. The feeds of the drills as indicated were as near to the values given in Table 5 and Fig. 1 as could be obtained. The actual speed in revolutions per minute is based on a peripheral speed of about 60 ft. per min. for all drill sizes. One part of soluble oil to 16 parts of water was used in all tests.

The results shown in the lower part of Table 6 were obtained similarly in drilling a medium cast iron, cast in bars 2 in. thick by 4 in. deep and 4 feet long, using the various drill diameters, operating at commercial feeds as for steel and using the same lubricant.

Formulas.—To make it possible to estimate the torque, thrust or power for any other combination of diameter and feed, the following equations were determined from experiments in which the drill diameter and feed were varied separately:

[4] See *Machine Design*, August, 1930, p. 49.

TABLE 5—SPEEDS AND FEEDS FOR DRILLS OF HIGH-SPEED STEEL IN VARIOUS METALS WITH A SUITABLE COOLANT

Size of Drill	Feed per Revolution	Bronze, Brass	Alloy-Steel Drop-Forging	Cast Iron	Tool and Carbon-Steel Drop-Forgings	Mild Steel	Malleable Iron	Cast Steel	Hard Cast Iron
		Ft. per Min.							
		300	50	140	60	120	90	40	80
In.	In.	R.P.M.							
1/16	0.003	18,320	3,056	8,554	3,667	7,328	5,500	2,445	4,889
3/32	0.0035	12,212	2,038	5,702	2,442	4,884	3,666	1,628	3,258
1/8	0.004	9,160	1,528	4,278	1,833	3,667	2,750	1,222	2,445
5/32	0.0045	7,328	1,221	3,420	1,465	2,934	2,198	976	1,954
3/16	0.005	6,106	1,019	2,852	1,222	2,445	1,833	815	1,630
7/32	0.0055	5,234	872	2,444	1,047	2,094	1,570	698	1,396
1/4	0.006	4,575	764	2,139	917	1,833	1,375	611	1,222
9/32	0.0065	4,071	678	1,900	814	1,628	1,222	542	1,084
5/16	0.007	3,660	611	1,711	733	1,467	1,100	489	978
11/32	0.0075	3,330	555	1,554	666	1,332	1,000	444	888
3/8	0.008	3,050	509	1,426	611	1,222	917	407	815
13/32	0.0085	2,818	469	1,316	563	1,126	846	376	752
7/16	0.009	2,614	437	1,222	524	1,048	786	349	698
15/32	0.0095	2,442	407	1,140	488	976	732	326	652
1/2	0.010	2,287	382	1,070	458	917	688	306	611
9/16	0.0105	2,035	339	950	407	814	611	271	543
5/8	0.011	1,830	306	856	367	733	550	244	489
11/16	0.0115	1,665	277	777	333	666	500	222	444
3/4	0.012	1,525	255	713	306	611	458	204	407
13/16	0.0125	1,409	234	658	281	562	423	188	376
7/8	0.013	1,307	218	611	262	524	393	175	349
15/16	0.0135	1,221	203	570	244	488	366	163	326
1	0.014	1,143	191	535	229	458	344	153	306
1 1/8	0.015	1,017	170	475	204	407	306	136	272
1 1/4	0.016	915	153	428	183	367	275	122	244
1 3/8	0.016	833	139	389	167	333	250	111	222
1 1/2	0.016	762	127	357	153	306	229	102	204
1 5/8	0.016	705	118	329	141	282	212	94	188
1 3/4	0.016	654	109	306	131	262	196	87	175
1 7/8	0.016	610	102	285	122	244	183	81	163
2	0.016	571	95	267	115	229	172	76	153

TABLE 7—DECIMAL POWERS OF FEED AND DIAMETER VALUES

f	$f^{0.32}$	$f^{0.4}$	$f^{0.6}$	$f^{0.78}$	d	$d^{0.2}$	$d^{1.8}$	d^2
0.006	0.325	0.1292	0.0464	0.0185	3/8	0.8219	0.1710	0.1407
0.007	0.336	0.1374	0.0509	0.0209	1/2	0.8705	0.2875	0.2500
0.008	0.346	0.1450	0.0552	0.0231	5/8	0.9103	0.4290	0.3905
0.009	0.355	0.1520	0.0592	0.0254	3/4	0.9441	0.5960	0.5625
0.010	0.363	0.1585	0.0631	0.0276	7/8	0.9736	0.7860	0.7655
0.011	0.371	0.1646	0.0668	0.0297	1	1.0000	1.0000	1.0000
0.012	0.378	0.1705	0.0704	0.0318	1 1/8	1.0238	1.2362	1.2660
0.013	0.385	0.1761	0.0739	0.0339	1 1/4	1.0456	1.4940	1.5625
0.014	0.391	0.1813	0.0772	0.0358	1 3/8	1.0658	1.7740	1.8910
0.015	0.397	0.1864	0.0805	0.0378	1 1/2	1.0845	2.0740	2.2500
0.016	0.403	0.1908	0.0837	0.0398				
0.017	0.408	0.1960	0.0868	0.0417				
0.018	0.413	0.2005	0.0898	0.0436				
0.019	0.418	0.2049	0.0927	0.0454				
0.020	0.423	0.2091	0.0956	0.0473				
0.021	0.427	0.2133	0.0985	0.0491				

For steel

$$T = C f^{0.78} d^{1.8} \quad (2)$$

$$B = K f^{0.78} d \quad (3)$$

For cast iron

$$T_{ci} = C_{ci} f^{0.6} d^2 \quad (4)$$

$$B_{ci} = K_{ci} f^{0.6} d \quad (5)$$

For S.A.E. 6150 steel, having a Brinell hardness of 187, C_{6150} is found to be 1840, so that Equation (2) then becomes

$$T_{6150} = 1840 f^{0.78} d^{1.8} \quad (6)$$

Constant K_{6150} for the same steel is found to be 53,400 so that Equation (3) becomes

$$B_{6150} = 53{,}400 f^{0.78} d \quad (7)$$

Constants C_{ci} and K_{ci} for cast iron also are determined from experimental values for any given set of conditions to be 380 and 14,720, so that Equations (4) and (5) become respectively

$$T_{ci} = 380 f^{0.6} d^2 \quad (8)$$

$$B_{ci} = 14{,}720 f^{0.6} d \quad (9)$$

Table 7, showing different values of f and d raised to various powers that are used in the foregoing equations, is provided for convenience in solving these equations. Numbers may be raised to a decimal power by the use of logarithms or by the graphical method given by W. F. Schaphorst[4]. Substituting in Equation (6) values from Table 7 for d and f corresponding to a drill diameter of 1½ in. and a feed of 0.015 in. gives the following:

$$T_{6150} = 1840 \times 0.0378 \times 2.074 = 144$$

which also corresponds to the experimental value of 143.3 given in Table 6.

TABLE 6—TORQUE, THRUST AND POWER IN DRILLING REPRESENTATIVE TEST BARS

Drill Diameter, In. d	Actual R.P.M. N	Feed, In. per Rev. f	Torque, Lb-Ft. T Test	Torque, Lb-Ft. T Formula	Torque Horsepower,[b] hp_t	Thrust, Lb. B Test	Thrust, Lb. B Formula	Thrust Horsepower[c], hp_b	Total Output, Hp.	Input, Kw. Gross	Input, Kw. Tare	Input, Kw. Net	Net Input, Hp.	Efficiency, Per Cent
Final Test Results on Steel Bar No. 6, S.A.E. 6150 Steel														
1/2	444.5	0.009	14.0	13.43	1.185	725	678	0.00732	1.193	1.6	0.67	0.93	1.244	96
5/8	368.0	0.011	22.3	23.4	1.562	838	990	0.00856	1.571	2.025	0.67	1.355	1.815	87
3/4	299.7	0.012	34.3	34.8	1.957	1,269	1,273	0.01153	1.975	2.42	0.67	1.75	2.34	84
1	228.1	0.013	62.4	62.4	2.71	1,862	1,820	0.01394	2.724	3.176	0.57	2.606	3.49	78
1¼	175.1	0.015	110.8	104.0	3.694	2,430	2,520	0.01611	3.710	3.87	0.57	3.3	4.42	84
1½	149.0	0.015	143.3	144.0	4.07	3,000	3,020	0.01693	4.087	4.507	0.507	4.0	5.35	76.5
Final Test Results on Cast-Iron Bar No. 18														
1/2	446.0	0.009	6.3	5.6	0.535	530	436	0.00614	0.541	1.12	0.67	0.45	0.602	90
5/8	364.4	0.011	10.2	9.9	0.708	645	615	0.00652	0.715	1.32	0.67	0.65	0.870	82
3/4	299.7	0.012	15.7	15.05	0.896	803	778	0.00728	0.903	1.48	0.67	0.81	1.084	83
1	229.8	0.013	27.9	28.1	1.221	1,088	1,088	0.00822	1.23	1.72	0.50	1.22	1.635	75.3
1¼	179.4	0.015	46.4	47.8	1.585	1,403	1,481	0.00954	1.60	2.025	0.45	1.575	2.110	76
1½	153.4	0.015	65.9	68.7	1.925	1,700	1,778	0.00988	1.94	2.27	0.37	1.90	2.550	76

[b] From Equation (11), using test values of T.

[c] From the formula $hp_b = fBN/(12 \times 33{,}000)$.

Also, from Equation (7)

$$B_{6150} = 53{,}400 \times 0.0378 \times 1.5 = 3020$$

which is 20 lb. higher than the experimental value given in Table 6.

The torque and thrust for a 1-in. drill cutting cast iron at a feed of 0.013 in. per revolution are found from Equations (8) and (9) respectively as follows:

$$T_{ci} = 380 \times 0.0739 \times 1 = 27.9$$

$$B_{ci} = 14{,}720 \times 0.0739 \times 1 = 1088$$

which check the experimental values given in Table 4.

Charts.—Fig. 2 presents a means for determining graphically the torque in pound-feet for any diameter of drill and any feed in the S.A.E. 6150 steel mentioned above. As illustrations, the torque for a ¾-in. drill operating at 0.012-in. feed is shown to be 35 lb-ft., and a 1-in. drill worked at 0.013-in. feed is shown to have a torque of 63 lb-ft. This chart is presented in two forms, one plotted on arithmetic scales and the other on log-log scales.

That the thrust for any combination of drill diameter and feed may be determined readily for the S.A.E. 6150 steel, Fig. 3 has been prepared. From this it is seen that the thrust for a ¾-in. drill operating at 0.012-in. feed is 1273 lb., and that of a 1-in. drill operating at 0.013-in. feed is 1820 lb.

Fig. 2 is based on Equation (6) and Fig. 3 on Equation (7). Actual test values vary slightly for some drills, because of the lack of geometrically similar shapes and proportions between the drills of different sizes.

Torque and Thrust for Other Materials

Table 8 shows torque constants C and thrust constants K for a variety of types of steel annealed to a hardness corresponding to the Brinnel number listed. To find the torque of any steel other than S.A.E. 6150, the constant C for that material may be used in Equation (2). Also the thrust constant K may be used in Equation (3) for thrust determination. Equations (6) and (7) are such equations for torque and thrust respectively for bar 6, S.A.E. 6150 steel.

TABLE 8—CONSTANTS AND FACTORS FOR TORQUE AND THRUST FORMULAS

Material S.A.E. No.	Bar No.	Brinell	Torque Formula C	Torque Factor	Thrust Formula K	Thrust Factor
1020	1	137	1,590	0.865	40,000	0.749
1045	2	159	1,590	0.865	42,000	0.786
2320	3	163	1,510	0.820	44,000	0.824
3120	4	143	1,510	0.820	39,000	0.730
3135	5	192	1,500	0.815	46,000	0.862
6150	6	187	1,840	1.000	53,400	1.000
3250	7	207	1,740	0.946	57,000	1.068
3140	8	196	1,550	0.843	50,000	0.936
2330	9	202	1,780	0.967	66,000	1.235
2340	10	207	1,840	1.000	65,000	1.218
6120	11	137	2,100	1.140	55,000	1.030
6130	12	156	2,000	1.087	56,000	1.049
6140	13	163	2,000	1.087	56,000	1.049
9250	14	202	1,800	0.978	63,000	1.180
Cr Mo	15	156	1,560	0.848	43,000	0.805
Cr Mo	16	156	1,700	0.946	48,000	0.899
1095	19	154	2,180	1.184	69,000	1.291
Cast Iron	18	163	380	....	14,720	....

In Table 8 also are listed torque and thrust factors which are obtained by dividing the torque constant C for the steel in question by 1840 and the thrust constant K by 53,400, the corresponding constant for S.A.E. 6150 steel, bar 6, as follows:

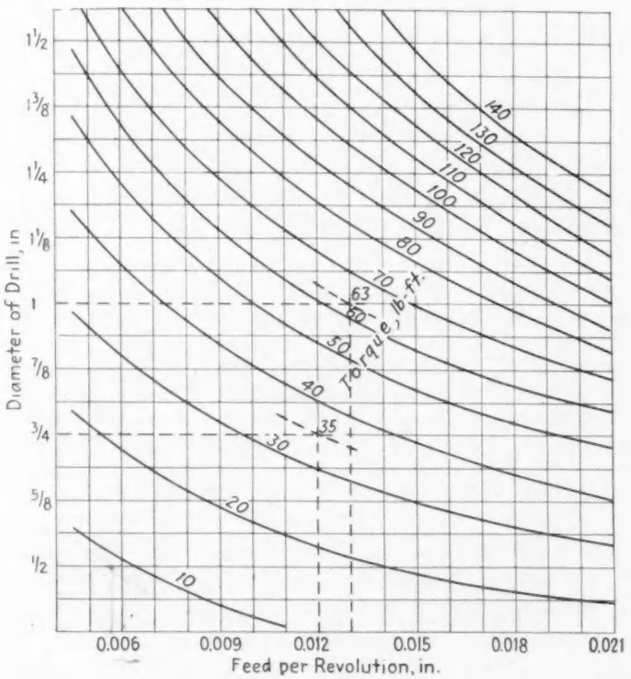
$$C_{1020}/C_{6150} = 1590/1840 = 0.865$$

$$K_{1020}/K_{6150} = 40{,}000/53{,}400 = 0.749$$

Thus, if the torque for drilling S.A.E. 6150 steel with a ¾-in. drill operating at 0.012-in. feed is found from Fig. 2 to be 35 lb-ft., the torque for the same drill operated at the same feed in S.A.E. 3120 steel would be equal to the 35 lb-ft. times the torque factor 0.820, determined from Table 8, which gives 28.7 lb-ft. Similarly, from Fig. 3, the thrust for the ¾-in. drill operating at 0.012-in. feed in S.A.E. 6150 steel is found to be 1273 lb. The thrust for S.A.E. 3120 steel, using the factor of 0.730 from Table 8, is found to be 930 lb.

Power Required for Drilling

Two values are of importance in using the power required to drill metal: first, the actual horsepower at the drill point, and second, the horsepower input as



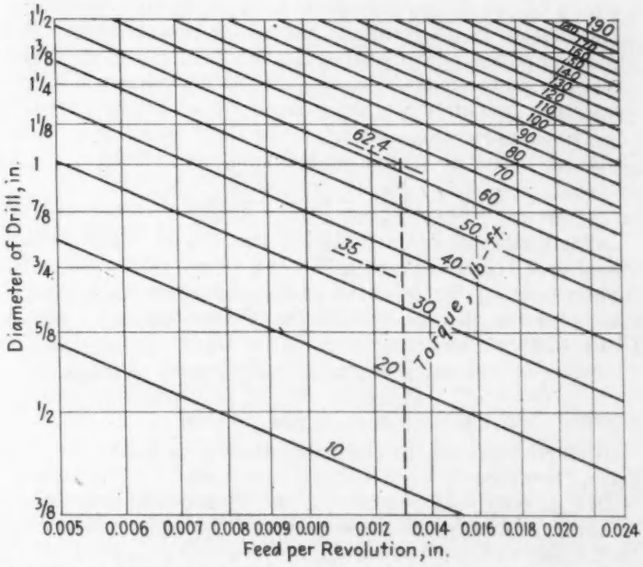


FIG. 2—TORQUE AT DRILL POINT IN DRILLING S.A.E. 6150 STEEL

This Chart Is Given in Two Forms. That at the Left Is Plotted on Arithmetic Scales While That Above Is Plotted on Log-Log Scales So That the Curves Become Straight Lines

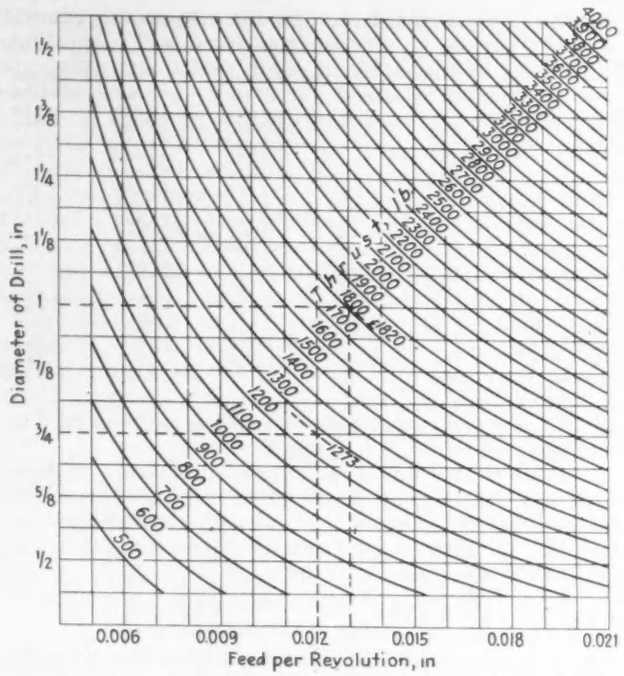


FIG. 3—DRILL THRUST IN DRILLING S.A.E. 6150 STEEL

developed by the motor. The computed horsepower-output at the drill point and the net horsepower-input developed by the motor are given in Table 6 for the various drill diameters and the corresponding commercial feeds. The net horsepower-input is the gross power developed by the motor less the frictional resistance of the machine running with speed and feed gears engaged but with the drill not cutting. These values, therefore, would have to be increased by from 10 to 40 per cent, according to the type of machine used, the number of gears in mesh and other conditions.

Perhaps the safest way to determine the actual power which would be developed by a motor on any particular installation is to compute the gross power-input from the computed power-output at the drill point by dividing the power-output by the estimated efficiency of the machine, which will range from 60 to 90 per cent.

The horsepower output at the drill point is a function of both the torque and thrust, as follows:

$$hp = \frac{2\pi TN}{33{,}000} + \frac{BfN}{12 \times 33{,}000} \qquad (10)$$

To illustrate, from Table 6, the 1¼-in. drill with a feed of 0.015 in., rotating at 1751 r.p.m., 60 ft. per min., when cutting S.A.E. 6150 steel, has a torque of 110.8 lb-ft. and a thrust of 2430 lb. Substituting in Equation (10) we have

$$hp = \frac{2\pi \, 110.8 \times 175.1}{33{,}000} + \frac{2430 \times 0.015 \times 175.1}{12 \times 33{,}000}$$
$$= 3.692 + 0.016 = 3.708$$

which corresponds to the value shown in Table 6. It is seen, however, that the horsepower due to the thrust, 0.016, is only 0.44 per cent of the total power developed. Therefore it may be neglected and the horsepower output based only on the torque.

Fig. 4 shows how the net-power values at the drill point may be determined graphically. These values are based only on the torque and speed, so that Equation (10) becomes

$$hp_t = 2\pi TN/33{,}000 \qquad (11)$$

To illustrate, the horsepower at the point of a 1-in. drill having a feed of 0.013 in. per revolution when rotating at 100 r.p.m. in S.A.E. 6150 steel is 1.17, as shown in Fig. 4. If the speed were 260 r.p.m., the actual horsepower would be 1.17 x 2.6, or 3.042. If this drilling were being done in a machine which had an efficiency of 78 per cent, the actual input to the machine for driving the drill at 260 r.p.m. would be 3.042 divided by 0.78, or 3.9 hp.

Power per Cubic Inch per Minute

The horsepower per cubic inch of metal cut per minute is equal to the horsepower at the drill point divided by the cubic inches cut per minute. Substituting the value of torque as given in Equation (2) for T in Equation (11) gives

$$hp_t = \frac{2\pi C f^{0.78} d^{1.8} N}{33{,}000} \qquad (12)$$

The cubic inches of metal cut per minute is

$$V = \pi d^2 f N/4 \qquad (13)$$

Dividing Equation (12) by Equation (13) gives the net horsepower per cubic inch per minute as follows:

$$hp/V = \frac{C}{4125\, d^{0.2} f^{0.22}} \qquad (14)$$

From Equation (6) C_{6150}, for S.A.E. 6150 steel, equals 1840, so that Equation (14) for the horsepower per cubic inch of that steel cut per minute becomes

$$(hp/V)_{6150} = \frac{1840}{4125\, d^{0.2} f^{0.22}} = \frac{0.446}{d^{0.2} f^{0.22}} \qquad (15)$$

The corresponding equation for cast iron is

$$(hp/V)_{ci} = C_{ci}/4125\, f^{0.4} = \frac{380}{4125\, f^{0.4}} = \frac{0.092}{f^{0.4}} \qquad (16)$$

These equations are independent of the drill diameter. Values of $d^{0.2}$, $f^{0.22}$ and $f^{0.4}$ may be obtained from Table 7.

If steels other than S.A.E. 6150 are to be used, the values obtained from Equation (15) may be multiplied by the torque factor for that particular steel, obtained from Table 8.

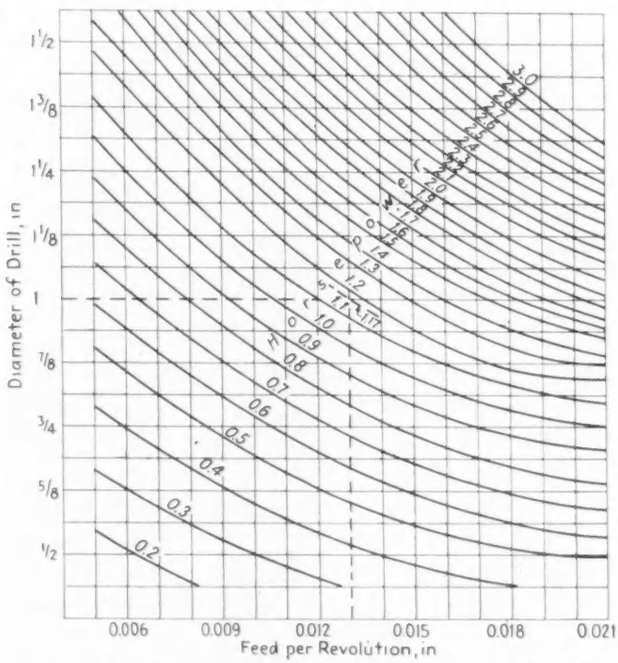


FIG. 4—NET POWER REQUIRED TO DRILL S.A.E. 6150 STEEL

To illustrate the use of Equations (15) and (16), the horsepower per cubic inch of metal cut per minute is determined for S.A.E. 6150 steel for a ½-in. drill at 0.009-in. feed by substituting corresponding values as follows:

$$(hp/V)_{6150} = \frac{0.446}{0.8705 \times 0.355} = 1.443$$

For a 1¼-in. drill at 0.015-in. feed

$$(hp/V)_{6150} = \frac{0.446}{1.0456 \times 0.397} = 1.075$$

In cast iron, the ½-in. drill with a feed of 0.009 in. gives

$$(hp/V)_{ci} = \frac{0.092}{0.1520} = 0.605$$

For the 1¼-in. drill with a feed of 0.015 in. the formula gives

$$(hp/V)_{ci} = \frac{0.092}{0.1864} = 0.493$$

Additional Discussion of Wear Tolerances on Gages

JOHN GAILLARD[2]:—Objections to the American Tentative Standard B4a-1925 on Fits were registered on behalf of Mr. Ovaitt when Mr. Bryant's paper was discussed.

Holes made to the American Tentative Standard are nominal to oversize, as shown in Fig. 1 for the nominal size of 1 in. The General Motors and Chrysler corporations have adopted hole tolerances extending downward from a line located 0.0005 in. above the nominal, as shown in Fig. 4 of the previous discussion. The question will be considered here whether General Motors holes[3] would be suitable for an American standard on fits intended to serve all industries of the Nation; also, the merits of the claims made for that system will be briefly discussed.

Each class of General Motors hole requires a different shaft to produce a fit with a given allowance, and no limits can be set for a shaft without knowing with which class of hole it is to be mated. This condition greatly complicates the problem of correctly fitting together external parts made in one place with internal parts made in another place. In the American Tentative Standard system, however, one specific shaft gives the same allowance with all classes of hole, and, conversely, shaft limits are independent of the class of the mating hole.

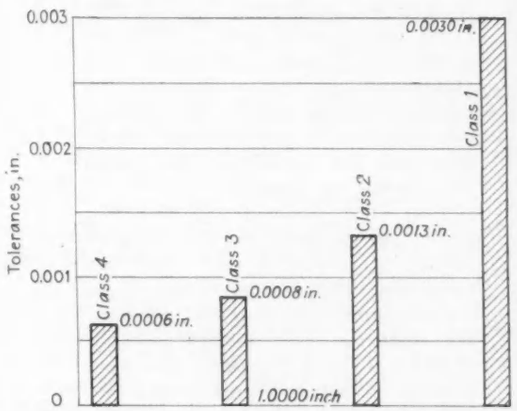


FIG. 1—TENTATIVE AMERICAN STANDARD TOLERANCES FOR 1-IN. HOLE

The low limit of a hole is the line where interference with a shaft may begin. This line must be carefully watched, else under certain conditions a tight fit may occur where a loose fit was meant, or conversely. There are six of these danger lines in the General Motors system, one for each class of hole. In the American Tentative Standard system there is only one such line, the nominal-size line. This facilitates the visualization of the fits by the designer and results in a reduction in the chance of confusion and errors.

Maximum efficiency in design and production requires standardization of fits; that is, of the limits for both mating parts, the holes and the shafts. No shafts have been standardized in the General Motors system, on the ground that shaft requirements are too variable. Nevertheless, it has been proved in practice that a relatively small number of different standard shafts will enable the designer to take into account all existing conditions, including such factors as length of hole. Standardization of shafts, however, can be carried out in a simple manner only if the holes have a common low limit, as specified in the American Tentative Standard. This statement is made without considering a basic-shaft system of fits, as this is regarded as irrelevant to the question being discussed. The General Motors series of holes would require a considerably larger number of shafts, and the resulting system of fits would be unduly complicated.

The tolerances on a given class of General Motors hole are constant throughout the entire range of diameters covered, from ⅛ in. to 3 in. inclusive. However, both from a theoretical and a practical viewpoint, a larger hole requires a larger tolerance, all other conditions being equal.

In the General Motors system, the Not Go plug-gage is the same for all classes of hole. In the American Standard system, all holes have the same Go gage, which is a more desirable condition because Go gages wear faster and consequently more of them are used.

Use of a reamer, as it wears down, for different classes of hole may also be applied to American Standard holes; only, the new reamer must then be transferred from the coarser to the finer classes. This is simply a matter of specifying the limits of the new reamers. Incidentally, General Motors reamers are special, as compared with present commercial stock reamers. Stock reamers are slightly oversize, while the limits of General Motors reamers are basic to undersize.

The use of bushings held between the same limits

(*Concluded on p. 392*)

[1] Late discussion of E. J. Bryant's Production Meeting paper. The paper was published in the S.A.E. JOURNAL for November, 1930, p. 553. The discussion presented at the meeting was printed in the S.A.E. JOURNAL for February, 1931, p. 210.

[2] Mechanical engineer, American Standards Association, New York City.

[3] See *American Machinist*, June 5, 1930, p. 903, and June 12, 1930, p. 956.

[4] See *American Machinist*, Nov. 6, 1930, p. 727.

[5] See *American Machinist*, Feb. 12, 1931, p. 289.

Diesel-Engine Motorcoach Operation and Maintenance

Annual Meeting Paper

By A. A. Lyman [1]

THE PERFECTION of automotive Diesel engines unquestionably is one of the most important developments now being carried on in the industry. Many fleet operators are eagerly waiting for suitable Diesel-powered commercial vehicles, and, as soon as the reliability and fuel economy of this type have been thoroughly demonstrated, the demand for them will doubtless be tremendously increased. As so few of these engines are in actual operation, the Diesel-engine experience of Public Service Coordinated Transport of New Jersey, although limited, probably is of more than ordinary interest.

The results to date are not regarded as definitely conclusive, but the principal advantages claimed for Diesel engines have been fairly well substantiated. The benefit of this experience is gladly made generally available, as it is hoped thereby to assist in stimulating Diesel-engine activity.

The results of operating European automotive Diesel engines that were installed in a gas-electric type motorcoach are briefly described. Coach operation and maintenance were satisfactory, the engines started easily, the exhaust was practically colorless and odorless, and the fuel-injection equipment gave no trouble.

The high fuel-mileage and low price per gallon effected a large saving in fuel cost, and other advantages were the elimination of carbon monoxide and the gasoline fire hazard. The author believes that it is sound policy for fleet owners to assist Diesel-engine development and thus hasten the time when all operators may enjoy the benefit of economical Diesel-engine operation.

Diesel Engines Imported

Investigating automotive Diesel engines in 1928, it was found that none were available in this Country; therefore a German truck engine was imported in August, 1929. This was of 105 mm. bore, 165 mm. stroke, developed 70 hp. at the governed speed of 1300 r.p.m., and weighed about 1400 lb. It was installed in a standard gasoline-electric 30-passenger motorcoach, and, as this was the first vehicle of its kind in America and of general interest, it was driven to the convention of the American Electric Railway Association in Atlantic City in October, 1929, where it was inspected by many operators and engineers. The results of operating in regular city service in Newark, throughout the winter of 1929 and 1930, showed wonderful fuel economy and indicated that the Diesel principle is practical for a motorcoach powerplant.

In March, 1930, an experimental Diesel motorcoach engine that represented later development was received from Germany, and, as the truck engine was not entirely suitable for coach service, it was replaced by this new model, which was of 100 mm. bore, 150 mm. stroke, developed 75 hp. at a governed speed of 1600 r.p.m. and weighed 1200 lb. After a period in Newark city operation, the coach made the 2000-mile round trip to the Society's Summer Meeting at French Lick, Ind., in May, 1930, after which it was returned to regular service.

The operating conditions in America with this combination electric drive were so different from those in Germany that the factory engineers desired the return, last fall, of this experimental engine for their inspection, and it was therefore replaced with a new model. This third engine is a redesign of the second one. The mechanical construction has been further improved and, although the power output is approximately the same, the engine runs more quietly. It has been operating in city service since October, 1930.

These engine models are of the solid-injection precombustion-chamber type, with removable cylinder-heads which contain the inlet and exhaust valves, fuel-injection valves, heater plugs and precombustion chambers. The water-cooling system is conventional, but starting and lighting equipment is rather uncommon, as a 24-volt starter is used with a 12-volt generator and accessories.

According to the manufacturer's specifications, the compression is about 500 lb. per sq. in., the maximum pressure of explosion 600 lb. per sq. in., and the fuel-injection pressure 900 lb. per sq. in. The precombustion chambers incorporated in the cylinder-heads contain the injection nozzles, heater plugs and "burners." A "burner" is essentially a secondary spray-jet through which precombustion forces the air-fuel mixture at high velocity into the main combustion-chamber. Standard Robert Bosch heater plugs and fuel-injection equipment are used, the pump being a multiple type having a plunger for each engine cylinder and constructed so that both the quantity of fuel and the time of injection can be regulated.

Complete Combination of Low-Grade Fuels

Before these engines were installed in motorcoaches, they were dynamometer tested at our shops, the most interesting results being the ability to run well on a wide range of fuels and the economical fuel consumption at all speeds and loads.

Fuels ranging in gravity from 26 to 40 deg. Baumé were used. Economy at full load for the entire range of operating speeds varied between 0.50 and 0.60 lb.

[1] M.S.A.E.—Automotive engineer, Public Service Coordinated Transport, Newark, N. J.

per b-hp-hr., and at one-third load the fuel consumption was not over 0.80 lb. per b-hp-hr. As further proof of complete combustion, the following exhaust-gas analyses are of interest:

	Carbon Dioxide, Per Cent	Oxygen, Per Cent	Carbon Monoxide, Per Cent	Other Combustibles, Per Cent
Full load, speed varied	9	9	0.03	Too little to indicate
Half load, speed varied	3	15	0.07	0.02
Idling ...	3	17	0.04	Not analyzed

These results show the presence at all times of excess oxygen, prove that carbon monoxide has been virtually eliminated, and that Diesel-powered vehicles are thus preferable from a public-health standpoint.

The type of motorcoach in which these engines were installed is a regular gas-electric 30-passenger model, weighing about 18,500 lb. without load. No change was made in the electrical propulsion equipment, and the standard gasoline-engine radiator was used, although it was found to be larger than is necessary. A conventional oil-filter of the cloth-cartridge type was installed in the fuel system as additional protection to the injection pump and nozzles. It has been found satisfactory to operate this Diesel-electric coach with fixed injection timing, but the quantity of fuel injected is regulated by the accelerator pedal, which thus controls the coach speed.

Operating Results

Before starting a cold engine, the electric heater-plugs are energized for about 30 to 45 sec., and only in extreme cases is longer heating required, but when the engine is warm it is unnecessary to use the heaters. Drivers are taught in a few minutes how to start the engine, and then the coach is controlled exactly the same as regular gas-electric vehicles.

This coach has been operated and maintained by three different garages and driven by a number of operators at each garage, which demonstrates that extraordinary care in operation or maintenance is not required. Unlike a gasoline motorcoach engine, experience shows that the Diesel requires no long warming-up period after starting, but can be driven almost immediately.

The road performance of the Diesel-engine coach is as good as that of gasoline-driven vehicles of equal power, and the exhaust is virtually colorless and odorless. No trouble is experienced with the engine's idling, both idling and maximum speeds being controlled by the governor. Passengers, in fact, do not realize that there is anything special about this coach, and no complaint has ever been received regarding it.

As previously stated, fuels used have varied in gravity from 26 to 40 deg. Baumé, initial distillation point 350 to 480 deg. fahr., end-point 550 to 775 deg. fahr., and viscosity 35 to 55 Saybolt Universal sec. at 100 deg. fahr. Owing to the extremely small clearances in fuel-pumps and injection valves, it is essential that automotive Diesel-engine fuel should be perfectly clean; centrifuging evidently is satisfactory. Fuel now being used with excellent results has the following characteristics:

Gravity, deg. Baumé	35
Viscosity at 100 deg. fahr., Saybolt Universal sec.	50
Flash-Point, closed cup, deg. fahr.	225
Distillation	
Initial, deg. fahr.	350
10 per cent, deg. fahr.	570
50 per cent, deg. fahr.	630
90 per cent, deg. fahr.	715
Final, deg. fahr.	760

The fuel costs have been remarkably low, as the consumption was only 60 to 70 per cent of that of gasoline coaches operating under identical conditions and the price per gallon is considerably less than that of gasoline. Another economy that would result from the use of fuel oil is the avoidance of gasoline evaporation during storage and handling. This may seem at first to be a trivial matter, but a normal evaporation loss of 2 per cent would mean a total yearly loss in our operation of $50,000.

In addition to actual operating results, the following information on the trip to French Lick last summer may be of interest. The round trip of 2000 miles was made by this city-type motorcoach at an average speed of 21 m.p.h., with a fuel mileage for the total trip of 7 miles per gallon, and as high as 11 miles per gallon was made in Ohio and Indiana. The latter mileage is equivalent to 110 ton-miles per gallon of fuel, which is regarded as excellent for this type of vehicle.

On the return trip it was necessary to replenish fuel in Pennsylvania, where only a poor grade of furnace oil could be obtained. As this fuel had virtually no lubricating qualities, engine oil was added to it, and the treated fuel was then used satisfactorily. The entire trip was made without trouble, no repairs or adjustments being required.

Maintenance

Experience has not substantiated the rather general belief that all Diesel engines run at extremely high temperatures and thus require more maintenance than gasoline engines; in fact, cooling-water and exhaust-gas temperatures are noticeably lower than in gasoline engines. The fuel-pumps, injection nozzles, burners, heater plugs and entire Diesel equipment have given satisfactory results. Injection nozzles and burners that have been removed for inspection have been found to be clean and in good condition.

Trouble experienced with the fuel system has usually been due to air in the injection pipes, which compresses without opening the nozzle valves and results in missing and loss of power. This condition usually is due to a leak in the fuel suction line, faulty fuel supply to the injection pump or failure of mechanics to relieve the air in the system after it has been opened.

Experience indicates that standard gasoline pumps must be made more powerful to satisfactorily handle the heavy and more viscous fuel. An electric pump at the main tank and another ahead of the filter on this coach now give satisfactory results and possess the advantage that air in the system can readily be expelled.

In this operation the Diesel engines have received but little special maintenance care.

The principal advantages of the Diesel motorcoach evidently are:

(1) Low specific fuel-consumption
(2) Ability to use low-priced fuel

(3) Elimination of fire hazard in motorcoaches and in the storage, handling and transportation of the fuel
(4) Appreciable reduction in service interruptions, as the entire ignition system is eliminated
(5) Practical elimination of carbon monoxide.

The principal disadvantages are:

(1) Exhaust smoke if any cylinder is not firing
(2) Increased size and weight of the engine

Regardless of these disadvantages, the results of more than one year's operation are very encouraging and demonstrate that great progress has been made abroad in the development of automotive Diesel engines. A considerate attitude and substantial encouragement on the part of operators will greatly assist domestic development. Considering the great saving in fuel costs that will result from the adoption of the Diesel engine, it is sound economic policy for fleet operators to assist this development and to have patience through any teething period that may occur during the early stages of operation.

It is hoped that our activities will stimulate interest in automotive Diesel engines and thus hasten the time when suitable truck and motorcoach models will be available for general adoption, that we may all enjoy the benefit of their economical operation.

THE DISCUSSION

CHAIRMAN O. D. TREIBER[2]:—While in Europe recently I drove some motorcoaches and trucks powered with the same kind of engine that the coach mentioned by Mr. Lyman has, and I noticed one thing particularly that Mr. Lyman did not mention; that is the high torque at low speeds. No matter how slowly the engine is run, even down to the minimum, it has tremendous torque yet runs smoothly, too. We naturally expect that Diesel engines will be a little rougher than gasoline engines of lower compression, but they are not objectionably rough; and the engines I saw in Europe ran absolutely as clean as any gasoline engine, with no smoke whatever. I was informed that about 500 engines of this same type were running in buses and trucks in Europe. Over here we have two, but we are going to have more and are going to have them pretty fast.

The Diesel-Engine Activity probably will have another Diesel-engine session at the next Annual Meeting, and I hope we can have some good papers at that time. I would like to suggest that at least two papers be given, one on the subject of the thermodynamics of oil engines or of engines which would include everything from a low to a high compression-ratio, and another paper that will give us a theoretical discussion of fuel oil. We engine builders do not know a great deal about oil; not as much as we shall have to know if we are ever to build really good Diesel engines. Furthermore, we have been a little slipshod about our thermodynamic analysis of this whole problem.

I want to mention one more thought that I have already seen agitated, I believe in a trade journal, about the name "Diesel." All kinds of definitions have been given to the word as applied to engines. Originally, the Diesel engine was a constant-pressure engine, with air-injection, and I have heard it insisted that an engine was not a Diesel engine unless it had air-injection with constant pressure, but we do not have any such thing any more and still we call them Diesel engines. We have solid injection, and mixed Otto and constant-pressure cycle, and Diesel engines operating also on the Otto cycle, so we are coming to the time when we shall have either to qualify this word Diesel in connection with engines or eliminate it and find some other word, because the engines we have now and those we are going to have are so far from the Diesel cycle as it was originally developed that there is no true comparison.

OLIVER F. ALLEN[3]:—Apropos of the size of automotive engines, at least one engine of 1000 hp. is in operation in the United States, driving a locomotive. Several oil-engine locomotives of 1500 hp. are in operation in Europe. The size of the automotive engine, as applied to rail service, is becoming quite large.

Supplementing what the Chairman said about the bus-engine situation abroad, at least six reputable experienced manufacturers are producing Diesel engines for trucks and buses. Of various makes of automotive oil engines on the Continent and in England, certainly more than 1000 are in regular operation, including several makes of which between 200 and 500 are in use. In some cities the entire bus systems are now Diesel operated.

CHAIRMAN TREIBER:—While in Europe I drove 11 different buses and trucks with Diesel engines made by 9 different manufacturers. One had been driven from May to September on the streets of large cities by 28 drivers. Many of the drivers said they did not know whether there was a gasoline or a Diesel engine under the hood. The engine could be started stone cold; it started and functioned the same as a gasoline engine.

A. A. LANE[4]:—Has Mr. Lyman determined how many miles of operation per year must be obtained from a Diesel engine to warrant the additional cost of the initial installation over that of a gasoline engine?

A. A. LYMAN:—We paid only slightly more for our Diesel engines imported from Germany than we do for domestic gasoline motorcoach engines, and we are saving in fuel costs somewhere between one-quarter and one-half of our gasoline costs. Of course, that is with electric-drive coaches. Because of the relatively high fuel-economy of a Diesel engine at part throttle, I think a greater proportionate saving would be effected in a straight merchanical-drive vehicle than in the electric-drive coach.

CHAIRMAN TREIBER:—If we had a 100-hp. gasoline engine and a 100-hp. Diesel engine running 10 hr. a day, 300 days a year, for two years, and paid 10 cents per gal. for gasoline and 6 cents for fuel oil, the gasoline engine would burn $6,600 worth of gasoline and the Diesel engine would burn something like $1,900 worth—a saving of $4,600 in two years with the 100-hp. engine. That means that you can pay $4,600 more for the engine, if you are going to run it 10 hr. per day for 300 days a year for two years, and still break even. But you will not have to pay that much more for it.

[2] M.S.A.E.—Chief engineer, Diesel division, Hercules Motors Corp., Canton, Ohio.
[3] M.S.A.E.—Consulting engineer, New York City.
[4] M.S.A.E.—Mechanical engineer, Gulf Companies Research Department, Pittsburgh.

Production Engineering

Metal Airplane Construction

Late Practice in Duralumin Construction Described and Low Jig-Cost Revealed[1]

WHILE I was a Naval lieutenant stationed at Detroit in 1920 as inspector of Naval aircraft, a contract for an all-metal torpedo airplane was let to the Stout Engineering Laboratories. At that time the small Junkers airplane was virtually the only all-metal plane in existence. Only now can it be realized how colossal was the undertaking for a small concern to build an all-metal plane of sufficient size to carry machine-guns and a 2000-lb. torpedo, when it was impossible to find men with experience in the utilization of duralumin either from the engineering or the structural standpoint.

That a plane was completed within one year and successfully flown with full load was a remarkable achievement, but the experimentation, dies and jigs required for the production of the completed structure then believed necessary were so costly that economical manufacture of a plane of that design was out of the question. However, the lessons learned by those who followed this work were invaluable, and the present Ford transport planes were developed from the knowledge gained.

The greatest handicap to the manufacture of all-metal aircraft today is the fact that the one-piece type of structure, ideal as to economy and simplicity of manufacture, is expensive because its stresses are indeterminate by conventional methods of analysis. The maximum of static testing is therefore required by the Department of Commerce to prove the assumptions on which the analysis is based.

Some legislation should be devised to correct this unjustifiable condition. The pioneering concern should not be forced to stand the burden of financing tests which furnish valuable information from which basic data are compiled for the benefit of the whole industry. The effect is to raise an insurmountable barrier in the path of the small, progressive manufacturer who is not strongly financed. I believe that this condition, more than any other one thing, retards the progress of aviation.

Recent static tests on one-piece structures, conducted at laboratories in Detroit, have furnished valuable data from which the necessary theoretical hypotheses for determinate calculations will undoubtedly be deduced soon.

Three of the advantages of the metal plane over the wood-and-fabric structure which can be assumed to be self-evident are freedom from fire hazard, appeal to the eye and longer life. Experience has proved that the relative safety of composite and metal structures in a crash is about the same in airplanes as in railroad coaches. Resistance to climatic change is better than that of laminated wood and doped fabric, and resistance to corrosion is better than that of steel tubing.

Specific Advantages of Metal Construction

Adaptability to mass production is shown by the facts that only about one-third of the floor space and one-eighth of the machinery is required for metal construction that is needed for wood and fabric, and still less machinery will be needed as the mills increase the variety of their dies and extruding forms for duralumin.

Virtually all of the skilled mechanics needed in a factory which specializes in duralumin construction are sheet-metal workers, while a great variety of trades are necessary in a factory in which planes of the conventional type are manufactured.

While duralumin now leads in the all-metal field, recent developments in alloy steel, magnesium and beryllium seem to foreshadow the day when these metals will take their place. Static tests on structural shapes made from Allegheny metal show a substantial advantage in strength per pound of structure; and the spot-welded connections show a surprising tenacity, a joint having three spot-welds equalling in strength one made with five rivets.

Duralumin construction has not been developed to the maximum, but definite figures are available as to its strength, and its peculiarities in fabrication are well known. Unquestionably duralumin lends itself to production more than does any other metal possessing anywhere nearly equal strength characteristics.

Heat-Treating Holds the Key

Slow aging after heat-treating is the greatest asset of duralumin in production. This quality makes possible bending, rolling, breaking or extruding thin metal during a period of 4 hr. after heat-treating, although it should not be submitted to great fabricating stresses after 1 hr. without reheating. Ordinary shapes can be formed from metal less than 0.049 in. in thickness on a brake or rollers without heat-treating. The heat-treating alone is not sufficient for forming shapes in which excessive stressing is necessary. The material should be annealed first, and heat-treating should follow the shaping.

Proper heat-treating is the secret of success in fabricating duralumin parts, and nitrate furnaces in which a definite and unvarying temperature can be maintained throughout the part are essential to assure satisfactory results.

Thorough cleansing of the parts, preferably in hot soda solution, is essential. The parts should be preheated after cleansing, the time varying according to the thickness of the material, 6 min. being an average time.

Working the material in the annealed or heat-treated state greatly hastens the aging process; and care must be taken to eliminate danger of cracking or checking, especially in bumping operations. Bending duralumin tubes and shapes by torch heat should be guarded against especially, as the uneven heat applied quickly disintegrates the grain of the metal.

Riveting Practice in Duralumin

Opinions differ on the question of punching or drilling holes for the utilization of rivets. However, those having the greatest experience in duralumin construction have almost entirely discontinued the punching of rivet holes or, where punching is still resorted to, the holes are reamed to size. Experience shows that slight cracks, which are hardly discernible to the eye, commonly develop in punching duralumin in the hardened state. Anyone who is familiar with the readiness of duralumin to fracture along a crack or scratch from vibration can readily understand the seriousness of such defects.

Hard or ST rivets are preferred by the more experienced builders to the SO or SH rivets. Utilization of the ST rivets involves careful supervision and strict regulation of heat-treating to eliminate the possibility of driving rivets that are excessively hard, with consequent enlarging of the rivet holes. While the use of the SO or SH rivets eliminates the necessity for repeated heat-treating of the rivets, a greater number is required, with additional drilling and aligning of holes, to obtain equal strength. Furthermore, when

(*Concluded on page* 392)

[1] From a Wichita Section Meeting paper by Frank M. Smith, vice-president and general manager of the Buckley Aircraft Co., Wichita, Kan.

CHARACTERISTICS OF AIRCRAFT EXHIBITED AT

PREPARED BY

	AIRCRAFT					ENGINES			
No.	Make	Nation	Model	Type	Purpose	Make	Model	Rated Horse-power	Speed, R.P.M.
1	Armstrong-Whitworth	Great Britain	Atlas	Biplane	Observation	Siddeley	Jaguar	400	1,700
2	B. F. W.	Germany	23 C	Monoplane	Touring	Argus	A s 8	80	1,400
3	Bernard	France	73 S	Monoplane	Sport	Gnome-Rhône	7 K b	300	1,600
4	Bernard	France	191 G. R.	Monoplane	Transatlantic	Hispaño	12 L b	600	2,000
5	Bernard	France	H. V. 42	Monoplane F. S.	High-speed training	Hispaño	.....	1,000	2,400
6	Blériot	France	111-4 T 4	Monoplane	Transport	Hispaño	12 J b	400	2,000
7	Blériot	France	125 T 12	Monoplane	Transport	2 Hispaño	12 H b r	2x500	2,000
8	Blériot	France	Spad 91–4 C 1	Biplane	Pursuit	Hispaño	12 H b	500	2,000
9	Blériot-Guillemin	France	J G 40	Monoplane	Ambulance	Salmson	9 A c	120	1,800
10	Breda	Italy	15 S	Monoplane	Touring	Walter	Mars	145	1,750
11	Bréguet	France	230 G. R.	Biplane	Transatlantic	Hispaño	12 N b	650	2,000
12	Bréguet	France	230 R 3	Biplane	Observation	Hispaño	12 N b	650	2,000
13	Bréguet	France	270 A 2	Biplane	Observation	Hispaño	12 H b	500	2,000
14	Bristol	Great Britain	Bulldog II A	Biplane	Pursuit	Bristol	Jupiter VII F	480	1,775
15	C. A. M. S.	France	58	Biplane H. S.	Transport	4 Lorraine	Algol	4x300	1,800
16	C. A. M. S.	France	80 R 3	Monoplane H.S.A.	Observation	Lorraine	Orion R	700	2,100
17	Caudron	France	180 Col. 3	Monoplane	Colonial	3 Lorraine	Algol	3x300	1,800
18	Caudron	France	193	Monoplane	Touring	Renault	.....	95	2,000
19	Caudron	France	232	Biplane	Touring	Renault	.....	95	2,000
20	Couzinet	France	30	Monoplane	Transport	3 Salmson	9 A d	3x40	2,000
21	De Havilland	Great Britain	Puss Moth	Monoplane	Touring	De Havilland	Gypsy III	105	2,000
22	Dewoitine	France	D. 27	Monoplane	Training	Gnome-Rhône	7 K b s	300	1,600
23	Dewoitine	France	D. 27 C 1	Monoplane	Pursuit	Hispaño	12 M b	500	2,000
24	Dewoitine	France	30 T 10	Monoplane	Transport	Hispaño	12 N b r	650	2,000
25	Dewoitine	France	35 T. 4	Monoplane	Transport	Hispaño-Wright	9 Q	300	2,000
26	Dornier	Germany	Do. S	Monoplane H. S.	Transport	4 Hispaño	12 L b r	4x600	2,000
27	Farman	France	190 T. 4	Monoplane	Transport	Farman	9 E b	250	2,150
28	Farman	France	200	Monoplane	Touring	Hispaño	6 P a	100	2,000
29	Farman	France	231	Monoplane	Touring	Renault	.....	95	2,000
30	Farman	France	301 T. 8.	Monoplane	Transport	3 Salmson	9 A b	3x230	1,700
31	Fiat	Italy	A. S. 2	Monoplane	Touring	Fiat	A. 50	85	1,600
32	Fiat	Italy	T. R. 1	Monoplane	Touring	Fiat	A. 50 S	95	1,600
33	Fokker	Holland	C. VIII-W	Monoplane F. S.	Observation	Lorraine	12 E b	450	1,850
34[a]	Fokker	Holland	F IX	Monoplane	Transport	3 Gnome-Rhône	Jupiter VI	3x480	2,000
35	Junkers	Germany	Junior	Monoplane	Touring	Siddeley	Genet	80	2,200
36	Latécoère	France	283	Monoplane	Postal	Hispaño	12 L b r	600	2,000
37	Latécoère	France	350 T. 12	Monoplane	Transport	3 Hispaño	12 J b	3x400	2,000
38	Levasseur	France	P L 11 R 3 b	Biplane F. S.	Observation	Gnome-Rhône	Jupiter VI	420	2,000
39	Levasseur	France	P L 12	Biplane H. S.	Training	Salmson	9 A b	230	1,700
40	Lioré-Olivier	France	203 B n 4	Biplane	Bombing	4 Gnome-Rhône	7 K b	4x300	1,600
41	Lioré-Olivier	France	H. 22	Monoplane H.S.A.	Postal	Gnome-Rhône	Titan 5 B c	240	1,800
42	Lioré-Olivier	France	H. 27	Monoplane H. S.	Postal	4 Hispaño	12 L b r	4x600	2,000
43	Lorraine-Hanriot	France	10 E D 2	Monoplane	Training	Lorraine	5 P a	100	1,350
44	Lorraine-Henriot	France	21 S	Monoplane	Ambulance	Lorraine	5 P c	120	1,700
45	Lorraine-Hanriot	France	H. 431	Biplane	Training	Lorraine	"Mizar" 7 M b	240	1,800
46	Morane-Saulnier	France	224	Monoplane	Pursuit	Gnome-Rhône	Jupiter VII 9 AS	465	2,000
47	Morane-Saulnier	France	230	Monoplane	Training	Salmson	9 A b	230	1,700
48	Morane-Saulnier	France	301	Monoplane	Training	Lorraine	5 P a	100	1,350
49	Morane-Saulnier	France	Moth	Biplane	Touring	De Havilland	Gipsy I	85	1,900
50	Mureaux	France	111 R 2	Monoplane	Observation	Hispaño	12 N b	650	2,000
51	National Aero Est.	Poland	P. VI	Monoplane	Pursuit	Bristol	Jupiter VI FH	420	1,700
52	National Aero Est.	Poland	P Z L 2	Monoplane	Training	Skoda-Wright	J 5	200	1,800
53	Nieuport	France	540 T. 8	Monoplane	Transport	Lorraine	Petrel	500	2,200
54	Nieuport	France	641 T. 4	Monoplane	Transport	Lorraine	Algol	300	1,800
55	Nieuport	France	82 C 1	Biplane	Pursuit	Lorraine	Petrel	500	2,200
56	Potez	France	36	Monoplane	Touring	Salmson	7 A c	95	1,800
57	Potez	France	39 A 2	Monoplane	Observation	Hispaño	12 H b	500	2,000
58	Potez	France	40 Col. 3	Monoplane	Colonial	3 Salmson	9 A b	3x230	1,700
59	Romeo	Italy	Ro 5 bis	Monoplane	Touring	Fiat	A. 50	85	1,600
60	Schreck-F. B. A.	France	290 T. 3	Biplane H. S. A.	Transport	Lorraine	Algol	300	1,800
61	Schreck-F. B. A.	France	310	Monoplane H.S.A.	Touring	Lorraine	5 P c	120	1,700
62	S. E. C. M.-Amiot	France	140 M	Monoplane	Multiplace Fighter	2 Lorraine	Orion	2x700	2,100
63	S. P. C. A.	France	40	Monoplane	Postal	3 Salmson	9 A c	3x120	1,800
64	Weymann	France	52	Monoplane	Touring	Renault	.....	95	2,000
65	Weymann-La Cierva	France	AutogyroC.19III	W. 201	Touring	Renault	.....	95	2,000
66	Wibault	France	280 T. 10	Monoplane	Transport	3 Gnome-Rhône	7 K b	3x300	1,600

Abbreviations: F. S.=Float seaplane; H. S.=Hull seaplane (flying-boat); A.=Amphibian.

[a] Duration at full speed for service machines and at cruising speed for civil machines.

PARIS AVIATION SALON, NOV. 28 TO DEC. 14, 1930

JOHN JAY IDE[1]

Dimensions				Weights			Loading		Performances										
													Climb to						
Span, Ft.	Lgth., Ft.	Hght., Ft.	Wing Area, Sq. Ft.	Wt., Empty, Lb.	Useful Load, Lb.	Total Wt., Lb.	Lb., per Sq. Ft.	Lb., per Hp.	Maximum Speed, at Gross Load M.P.H.	Maximum Speed, M. P. H. at Feet	Cruising Speed at Gross Load, M.P.H.	Minimum Speed, M.P.H.	3,280 Ft., Min.	6,560 Ft., Min.	9,840 Ft., Min.	13,120 Ft., Min.	16,400 Ft., Min.	Service Ceiling, Ft.	Duration, Hr.[a]	No.
39.6	27.8	10.0	391	2,900	1,130	4,030	10.3	10.1	142	132 at 10,000	.....	.....	3.7	.....	13	.....	36	16,800	3.25	1
39.4	24.3	7.2	154	705	617	1,322	8.6	16.5	112	.....	95	.....	4.2	.....	.....	.....	.....	20,355	.....	2
30.2	22.0	.....	145	1,537	566	2,103	14.5	7.0	174[b]	171 at 13,120[b]	.....	72[b]	.....	.....	.....	.....	.....	26,240[b]	1.5[b]	3
56.7	42.0	12.8	462	5,269	7,319	12,588	27.2	21.0	130	.....	109	.....	9	.....	.....	.....	.....	.....	.....	4
30.2	.....	.....	145	3,086	.....	.....	.....	.....	267	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.5	5
55.8	34.9	13.2	380	3,527	2,425	5,952	15.7	14.9	.....	.....	124	.....	.....	.....	.....	.....	.....	.....	.....	6
96.4	45.3	13.1	1,076	8,664	5,225	13,889	12.9	13.9	127[b]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7
28.4	20.7	8.9	237	2,496	804	3,300	13.9	6.6	.....	168 at 13,120	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
48.2	26.1	11.8	269	1,499	661	2,160	8.0	18.0	93	.....	78	.....	.....	.....	.....	.....	.....	16,400	4	9
35.4	22.3	7.2	194	1,036	705	1,741	9.0	12.0	130	.....	115	43	.....	.....	.....	.....	35	21,320	6	10
60.0	35.1	13.4	646	4,828	9,943	14,771	22.9	22.7	155	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11
57.4	36.1	13.4	600	3,882	4,055	7,937	13.2	12.2	.....	149 at 6,560	137	.....	.....	9	.....	.....	28.8	21,320	9	12
55.8	32.1	11.8	535	4,012	1,830	5,842	10.9	11.7	149	133 at 16,400	134	.....	3.1	6.2	9.8	14.3	20.3	25,910	.....	13
31.5	23.0	9.5	265	2,382	1,108	3,490	13.2	7.3	.....	177 at 9,840	.....	.....	2.3	4.3	6.5	8.4	11.1	28,000	.....	14
79.7	48.7	20.1	1,399	10,582	8,157	18,739	13.4	15.6	137[b]	134 at 4,920[b]	112[b]	.....	.....	.....	24[b]	.....	.....	14,760[b]	6[b]	15
80.7	42.3	16.7	671	6,118	2,976	9,094	13.5	13.0	129[b]	.....	.....	.....	.....	.....	.....	.....	.....	19,680[b]	6.5[b]	16
80.4	50.2	12.5	753	7,006	4,017	11,023	14.6	12.2	.....	137 at 6,560[b]	124[b]	71[b]	.....	.....	.....	.....	.....	22,300[b]	5[b]	17
37.7	24.6	10.4	148	1,058	617	1,675	11.3	17.6	106	.....	90	.....	.....	.....	.....	.....	.....	14,760	4.5	18
32.5	24.4	8.9	258	1,014	705	1,719	6.7	18.1	99	.....	84	42	.....	.....	.....	.....	.....	13,775	5	19
52.5	34.1	8.8	323	2,205	1,322	3,527	10.9	27.7	102	.....	93	.....	.....	.....	.....	.....	.....	9,840	5.5	20
36.8	25.0	6.8	222	1,200	850	2,050	9.2	19.5	128	.....	110	42	.....	.....	18	.....	.....	18,000	.....	21
33.8	21.3	9.5	188	1,790	697	2,487	13.2	8.3	149	140 at 13,120	.....	51	.....	.....	8.2	12.0	.....	24,600	.....	22
32.1	21.3	9.5	188	2,138	794	2,932	15.6	5.9	180	169 at 16,400	.....	56	.....	.....	.....	.....	9.7	30,340	.....	23
82.0	48.7	13.5	699	5,458	4,431	9,889	14.1	15.2	133	.....	.....	69	.....	.....	.....	.....	.....	19,680	4.5	24
39.9	30.1	9.8	269	2,160	1,720	3,880	14.4	12.9	133	.....	112	.....	.....	.....	.....	.....	.....	13,120	.....	25
101.7	84.5	24.8	2,249	20,415	12,654	33,069	14.7	13.8	127	.....	65	62	.....	.....	.....	.....	.....	.....	7	26
46.2	32.8	9.8	430	2,271	1,697	3,968	9.2	15.9	124	.....	106	50	6	13	23	35	62	18,040	.....	27
36.7	29.5	8.5	269	1,367	838	2,205	8.2	22.0	96	.....	87	.....	.....	.....	.....	.....	.....	9,840	3.6	28
29.8	20.3	6.6	156	838	595	1,433	9.2	15.1	118	.....	99	43	.....	.....	.....	.....	.....	13,120	3.7	29
62.7	44.0	10.5	710	6,019	3,968	9,987	14.1	14.5	140	.....	115	.....	3.2	7.8	14.5	25.2	48.7	16,400	6	30
34.1	20.7	8.2	188	1,014	617	1,631	8.7	19.2	109	.....	99	43	.....	.....	.....	.....	.....	.....	7	31
29.5	21.5	8.5	145	992	617	1,609	10.0	16.9	118	.....	102	43	.....	.....	.....	.....	.....	.....	5	32
59.0	37.8	12.5	474	4,221	1,841	6,062	12.8	13.5	125	.....	106	59	5.4	12.3	21.8	37.0	.....	14,100	5	33
89.0	63.3	15.8	1,109	12,012	7,824	19,836	17.9	13.8	130	.....	107	67	7	16.5	31	.....	.....	11,800	5.5	34
32.8	23.3	7.9	147	772	550	1,322	8.9	16.5	106	.....	87	.....	6	14.4	27.6	.....	.....	15,700	4.3	35
63.2	44.8	16.4	624	5,732	5,952	11,684	18.7	19.5	136	.....	106	.....	.....	.....	.....	.....	.....	11,480	25.0	36
73.3	49.1	11.6	805	8,311	4,630	12,941	16.1	10.8	149[b]	.....	124[b]	.....	.....	.....	.....	.....	.....	19,680[b]	4[b]	37
46.6	32.8	14.8	619	4,189	1,984	6,173	10.0	14.7	106[b]	.....	.....	59[b]	.....	16[b]	.....	.....	.....	11,480[b]	3[b]	38
42.6	29.3	10.9	333	2,255	1,272	3,527	10.6	15.3	106[b]	.....	.....	50[b]	.....	30[b]	.....	.....	.....	.....	3[b]	39
80.5	47.6	16.1	1,334	8,827	5,723	14,550	10.9	12.1	121[b]	.....	.....	.....	.....	9.7[b]	.....	.....	.....	17,710[b]	.....	40
52.3	33.8	12.6	355	2,954	1,014	3,968	11.2	16.5	109[b]	.....	99[b]	.....	.....	16.5[b]	.....	.....	.....	13,120[b]	4[b]	41
111.5	70.4	21.3	1,775	19,841	18,298	38,139	21.5	15.9	140[b]	.....	124[b]	.....	.....	.....	.....	.....	.....	9,840[b]	20[b]	42
39.0	24.4	9.2	237	1,305	569	1,874	7.9	18.7	91	87 at 3,280	.....	.....	7.1	17.7	.....	.....	.....	12,790	3.5	43
40.3	25.6	9.6	275	1,499	661	2,160	7.8	18.0	87	.....	.....	37	10	21	.....	.....	.....	15,745	5	44
37.4	26.2	10.8	325	2,105	915	3,020	9.3	12.6	114	107 at 6,560	.....	.....	5.2	11.8	20.2	37.3	.....	15,150	2.5	45
34.1	23.3	9.8	183	2,282	804	3,086	16.9	6.6	.....	183 at 13,120[b]	.....	.....	.....	.....	.....	.....	.....	31,160[b]	.....	46
35.1	22.8	9.2	212	1,786	749	2,535	11.9	11.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	47
39.4	24.6	8.5	232	1,482	619	2,101	9.1	21.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	48
29.9	23.9	8.8	242	959	789	1,748	7.2	20.6	102	.....	81	45	.....	.....	35	.....	.....	14,430	.....	49
50.5	32.8	11.9	375	3,175	1,783	4,958	13.2	7.6	169[b]	160 at 16,400[b]	.....	60[b]	.....	.....	.....	.....	12.2[b]	25,910[b]	.....	50
33.8	23.5	9.0	186	1,947	1,007	2,954	15.9	7.0	181	174 at 16,400	.....	64	.....	2.8	.....	.....	9.2	29,520	.....	51
44.0	25.9	8.8	278	1,940	886	2,826	10.2	14.1	114	93 at 16,400	.....	39	4.2	10.5	18.3	31.2	55.3	.....	.....	52
76.8	49.2	12.5	646	5,190	3,298	8,488	13.1	17.0	133	123 at 9,840	122	63	7.3	15.3	26.7	48.7	.....	15,285	4	53
50.5	31.0	10.5	332	2,710	1,479	4,189	12.6	14.0	130	.....	112	56	6.7	15.7	28.8	53.0	.....	16,400	4	54
39.4	24.6	9.8	301	2,853	674	3,527	11.7	7.0	168	165 at 16,400	132	67	1.5	3.2	5.2	7.5	10.3	30,995	2	55
34.2	24.1	8.1	215	939	648	1,587	7.4	16.7	99	.....	.....	53	5.9	.....	.....	.....	.....	13,400	.....	56
52.5	33.3	11.1	377	3,505	1,455	4,960	13.2	9.9	149	142 at 11,480	.....	56	2.8	.....	9.25	.....	20.0	25,255	4	57
60.7	47.2	11.3	678	6,296	3,117	9,413	13.9	13.6	132[b]	109 at 16,400[b]	.....	.....	3.5[b]	7.7[b]	14.4[b]	22[b]	40.4[b]	16,400[b]	.....	58
36.8	23.1	6.8	204	882	617	1,499	7.3	17.6	109	.....	93	37	.....	.....	.....	.....	.....	16,400	6.5	59
43.0	31.2	13.1	432	3,042	1,323	4,365	10.1	14.5	106[b]	101 at 6,560[b]	87[b]	.....	9[b]	19[b]	30[b]	.....	.....	13,450[b]	4[b]	60
39.4	24.9	10.2	226	1,587	551	2,138	9.5	17.8	87	.....	74	.....	9	23	52	.....	.....	11,480	2.5	61
80.4	55.8	11.5	1,076	9,304	3,240	12,544	11.6	8.9	150[b]	146 at 16,400[b]	.....	53	2[b]	.....	.....	15[b]	17[b]	26,240[b]	4[b]	62
65.6	42.6	10.8	592	5,013	1,918	6,931	11.7	19.2	112	.....	99	.....	.....	.....	.....	.....	.....	12,135	3.5	63
39.4	30.5	10.2	258	1,080	573	1,653	6.4	17.4	93	.....	78	37	.....	.....	.....	.....	.....	.....	4	64
35.1	35.1	11.1	91	939	461	1,400	15.4	14.7	99	.....	.....	.....	4.4	.....	.....	.....	.....	.....	.....	65
74.1	55.8	18.9	690	7,837	4,839	12,676	18.4	14.1	133	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	66

[b] Estimated.

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Transportation Engineering

Vehicle-Type Selection

How to Select Suitable Motor-Vehicle Equipment, Stated by A. J. Scaife[1]

NO specific data or set values exist to aid one in selecting his motor-vehicle equipment. Consideration should be given, therefore, to the type of equipment that will best fit into the kind of work to be performed. It is necessary to determine whether the loads to be hauled are heavy or light, for long or short distances, and at low or high speeds. This determination can be considered under two divisions:

(1) A vehicle should be of sufficient size, sturdily constructed so as to give long life, designed to give the most efficient operation, and of sufficient capacity to carry the load without overloading.

(2) The other side of the problem is that of appearance or style. This we believe to be at least of equal importance with that of the ability of the vehicle.

In selecting this vehicle, consideration should be given to providing ample-sized pneumatic tires, of either the balloon or the high-pressure type. It is advisable to use tires that are slightly larger than the normal requirements to get the greatest tire-mileage.

The gear ratio in the rear axle should be chosen with reference to the territory in which the vehicle is to operate. If it is to be operated in hilly country, it is desirable to have an axle ratio high enough numerically to take care of the requirements without undue labor on the part of the engine.

When operating in a fairly level or slightly rolling country, it is advisable to take advantage of this condition by selecting an axle ratio of a lower numerical ratio value. This is not so complicated as it sounds, because it is usually possible to confine these selections to two axle-ratios and, in the greatest extreme, to three axle-ratios.

The transmission can be of a three or a four-speed type. We recommend that the four-speed type be used in trucks of 1½-ton capacity or over. This will give ample ability in difficult or hard going and fairly good road-speeds in good going.

The engine can have either four or six cylinders, according to the requirements. If deliveries are to be made in closely built-up communities where very few miles are covered per day either by a light or a heavy-duty truck, a four-cylinder engine is very satisfactory. If deliveries are to be made with light or heavy loads and over long haulage-distances the more flexible unit, the six-cylinder engine, is advisable.

Factors Other than Strength and Power

In making a selection, it is necessary that something besides the strength and power of the vehicle be considered, as there is no question that the vehicle will carry the load with an ordinary platform or enclosed body built up with the roughest sort of material, but this would not be feasible nor would it be good business.

It is a well-known fact in department-store delivery service that a sale is never completed until the goods have been delivered and accepted by the purchaser, and that the method of delivery of the goods is a most important factor in completing the sale. This is one of the reasons why the department stores own and control their motor-vehicle equipment, because it gives them complete supervision over the delivery system, the condition of the vehicle and the appearance of the operator. We have been informed that, in many instances, the customers have complained to the department store about the noisy, dirty or rundown condition of the vehicle and the untidy appearance of the operator, and have notified the merchants that they will refuse to accept further deliveries from that type of equipment. There should be no question then that neat-appearing, clean, well-designed, uptodate motor-vehicle equipment is needed for use in merchandising.

Cost of Operation a Factor

We should realize that, to operate efficiently, it is necessary to give the equipment adequate care in a suitably equipped place. Satisfactory maintenance is extremely important. It is difficult to get comparative costs that mean anything, because there is no uniform method of keeping records. But the Transportation and Maintenance Activity Committee of the Society is now devising a Uniform Method of Cost Comparison plan whereby a uniform system of record-keeping will be used so that, when comparisons are made, they will really mean something.

To get uniform costs, we have divided them into fixed and operating costs as follows:

Fixed Costs	*Operating Costs*
(1) Insurance	(1) Gas
(2) License	(2) Lubrication
(3) Storage	(3) Tires
(4) Taxes	(4) Repairs and Maintenance
(5) Interest on Investments	(5) Depreciation
(6) Supervision and Overhead	(6) ———
(7) Driver	(7) ———

Fixed costs are those which accrue over a period of time, whether the truck actually is operated continuously or not. For that reason they are figured by the year, month, week or day. Operating or variable costs, however, apply only when the truck is operated; therefore they have a more direct relation to mileage than to time.

Cost estimates must include all expense items in both groups, properly interpreted in the cost total for each vehicle, and translated into an average per mile, day or other needed unit.

The costs of insurance, taxes, interest and sometimes licenses are based upon the total investment in the truck at the delivery point. Such a figure must include chassis net price, body net price, freight and handling.

Variable Costs Considered

The second group of costs, known as variable or operating costs, is directly affected by a number of factors such as type of operation, kind of road, load carried, tires used, degree of traffic congestion, number of stops per mile, maintenance methods, driver's skill and wage, climatic conditions and average daily mileage.

Even a casual consideration of a few of these factors indicates at once how widely the variable costs will vary for a given model under different conditions, and how utterly impossible it is to determine these costs at all accurately without a careful survey of each installation by an engineer trained to recognize the influence of each factor upon actual costs. The only figures available are what amount to standard or basic estimates of variable costs for what can be termed average or fair conditions.

[1] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

Driver Training Featured

Lectures to Drivers in Instruction School Found Beneficial by Akron Transportation Co.

AT THE SCHOOL of Instruction for transportation-department employes of the Akron Transportation Co., Akron, Ohio, a series of lectures is given which applies directly toward enabling the drivers of the motorcoaches operated by the company to acquire a comprehensive understanding of the company's requirements, so that the drivers may have every opportunity to learn the basic reasons which underlie the company's policy in governing the transportation service given in Akron and its environs.

Some of the more important points are covered in the following excerpts from the lectures mentioned. These instructions have proved very efficacious in securing wholehearted cooperation from the drivers and have encouraged them to give the company and the public their undivided interest in their work, to the satisfaction of all concerned.

An endeavor is made in these lectures to state the whys and wherefores of operating rules, the principles and practices relating to safety and the avoidance of accidents, how to deal with the public in the matter of collecting fares, the necessity for drivers' compliance with the route schedules which have been laid out, and numerous other important matters which afford the drivers opportunity to understand thoroughly their position and the work they are expected to do. For a full exposition of the methods maintained in the School of Instruction, reference is made to a paper entitled, Driver-Training for Maintenance Cost-Reduction, by J. S. Lowe.[1]

Necessity for Operating Rules

Understanding of the underlying spirit of any rule is gained by realization of the wisdom and necessity for the rule, rather than by obedience merely because it is a rule. No rule seems unjust after a driver analyzes it and learns that it is wisely worked out on the basis of the company's experience and that the rule is made necessary by existing conditions. The object of devising and enforcing a rule is to point the way which a company's experience has proved to be the best one to follow, without infringing upon the rights of anyone.

The prime object of rules is to enable an organization to conduct its transportation system in the most cooperative manner, to give the employes the benefit of long experience and save them from taking unguided steps, as well as to enable them to grow in the knowledge of their work and become a credit to themselves and to the company. Intimate knowledge of and obedience to all rules will enable an employe to render a satisfactory and praiseworthy service. When he entered the company's service, he expressed his willingness to comply with all rules set forth by the company; therefore, to safeguard life and limb and also to protect property, it is necessary that he be familiar with all rules governing his work, since ignorance of any rule is no excuse for negligence or for omission of any duty.

Rules Governing Accident Reports

Mr. Lowe's company appreciates the fact that it is impossible to operate a large fleet of motorcoaches without experiencing a few accidents. Therefore, the company requires from each driver an intelligent written report of all accidents or unusual occurrences which happen on or near his vehicle, in addition to his regular reports pertaining to his daily duties.

Accidents of seemingly trivial nature should never be neglected. Frequently, accidents of this type cause the most trouble and inconvenience. Claimants continually call at the claim department for adjustments not covered by reports. These are termed "blind cases" and in many instances the company is forced to pay damages. If the case had been covered by a report, the company might have been able to prove that it was not at fault. All accident reports should be recorded the same day they occur. This enables a driver to make a more accurate report while the details are fresh in his mind. It also gives the proper officials the necessary information at the earliest possible moment.

Before filling in an accident-report blank, a driver should previously read and understand all the questions. He can then fill in quickly the answers to the questions pertaining to the accident in which he is involved and check those which do not. He should use carbon paper that is in good condition and placed properly under the original sheet, writing with a medium hard pencil and moderate pressure to assure making readable carbon copies.

Courtesy is the cornerstone of the foundation of self-discipline, in the belief of Mr. Lowe's company. A driver cannot expect others to respect him if, in his actions, he demonstrates no self-respect. It is good nature, rather than excessive politeness, that passengers have a right to expect from a man who receives their money for a service offered and sold to them. To maintain the harmony which is essential in business relations, there is need for a lubricant. Just as oil is a lubricant for machinery and reduces friction, so does courtesy in business intercourse smooth the rough places, disarm unreasonable criticism and invite goodwill. Courtesy goes hand in hand with enthusiasm, thus comprising two of the factors essential for the success of any business. These attributes apply, not only to the operating officials, but should exist throughout all departments and in all ranks.

Even though a company may have control over the major portion of the transportation business in a given city, this is no reason for drivers to assume an independent and discourteous attitude toward the public. The fact that the company may be large is all the better reason why all drivers should render a service beyond reproach; for, the larger a public-utility company is, the larger is the target for public criticism. The individuals who constitute the public seldom meet any representative of the company other than the driver of a public-utility conveyance, and the company is commended or condemned according to the nature of his actions. The patrons of the service include persons of all classes, and all are entitled to the courteous treatment that should be practised under all circumstances.

An opportunity may present itself wherein the passengers may greatly assist the driver in a time of need. If they have been given courteous service, they will be willing to help him. A driver should think of himself as a host and treat his passenger-guests as he would like to be treated if he were himself a passenger. Discourtesy on the part of a driver reflects on all drivers; but courtesy is rewarded by a corresponding consideration from all those with whom a driver comes into daily contact.

Accurate Fare-Collection Essential

Since a transportation company is in business for the same reason that other companies are in business, to make money, and is dependent upon an accurate collection of fares taken in through fare-boxes on its vehicles, one of the foremost duties of each driver is to make certain that the company is compensated for every passenger carried. While the loss of one fare seems insignificant when the rate of fare is relatively small, if each driver were to lose one fare each trip per day, the loss in revenue would, in a year, amount to thousands of dollars. Ser-

[1] General superintendent of transportation, Akron Transportation Co., Akron, Ohio. The paper was published in the November, 1930, issue of the S.A.E. JOURNAL, beginning on p. 591. The discussion of the paper appeared in the February, 1931, issue of the S.A.E. JOURNAL, beginning on p. 224.

vice without proper compensation can not long exist.

A driver occasionally may encounter a passenger who attempts to escape payment of his fare, but an alert driver can in most instances obtain payment of fare with little difficulty. Tactfulness should be exercised, to avoid creating the impression that the collection of fares is the prime consideration. Drivers are often censured because of their brusque or disagreeable methods of fare collection.

Maintaining Schedules Is Difficult

In Mr. Lowe's company it has been found that the difficulties of maintaining schedules have caused more trouble for the drivers on this system than has any other one thing. While schedules are necessary to successful operation, they are not meant to be adhered to at whatever cost but come in fourth place in his company's scheme of operation. Schedules are important inasmuch as they inform a driver when he is to go to work, when he is to finish his day's work, the time at which he is to leave the garage and the time at which he is due at the terminals of the line over which he drives. They include more than merely driving from one end of the line to the other, and are based upon the assumption that the driver will discharge his duties faithfully along the way.

The headway time between motorcoaches and equal distribution of service on a line are determined by the schedules, and drivers should endeavor to maintain an even headway. If one driver runs a little ahead of the schedule, the time interval between his vehicle and the one following him is greater than it should be. This constitutes a hardship for the driver who is following, because the second driver gets more than his share of the passengers, which causes crowding and prevents the passengers from being benefited by the adequate service supplied. The company also suffers from the effect that conditions of this kind have on revenue.

When taking a motorcoach out of the garage for a "run," a driver should leave according to schedule and should arrive at the end of the line on time. Some routes provide heavy loads of passengers on the first trip, and a late start often offsets the possibilities for a successful day's work. It is doubtful that Mr. Lowe's company would receive many complaints of discourteous drivers or be involved in very many accidents if the drivers always allowed themselves sufficient time to perform their necessary duties. The schedule should not hinder a driver from doing his duty. If a driver indicates by his actions that he is late and in a hurry, the passengers feel nervous and uneasy while riding. Accidents often happen under such conditions. If a driver bears in mind that, by living up to his schedule to the minute he will eliminate some of the difficulties in maintaining the schedule, he will lighten his work considerably.

Production Engineering

(*Concluded from p.* 387)

the plane is exposed to salt water or spray, electrolysis sets in between the duralumin skin and the softer rivet, resulting in corrosion of the rivet.

More Duralumin Shapes Are a Help

The limited amount of metal aircraft construction has handicapped the manufacturers of duralumin, but they are constantly in touch with the engineers of plants producing all-metal planes and are experimenting in the fabrication of new shapes. Rolled or extruded sections of virtually every shape used in the construction of certain models of all-metal plane can now be purchased. The advantage of this is great, as it reduces production to a matter of assembly, eliminating some expensive equipment and skilled mechanics and saving in floor space, dies, forms and jigs.

A mistaken idea seems to be prevalent that providing the jigs for all-metal construction is more expensive than for composite construction. The fact will therefore be of interest that the total expense for jigs, dies, forms and patterns for a recent four-place all-metal plane, all of which are available for future production, was less than $3,000, and not more than $3,000 additional will be necessary to provide for a reasonable production program on the same plane. That the cost of dies for a certain well-known two-place composite plane was more than $35,000 and the cost of jigs for the same plane was more than $15,000 gives some idea of the advantage in favor of all-metal construction, especially when it is considered that changes in design may involve a total loss of the cost of the dies and jigs.

A series of experiments with smooth and corrugated surfaces has shown that, while the corrugated surface had an actual area that was 15 to 20 per cent greater than the smooth surface, the horsepower required was only 2 per cent greater at high speed, 1 per cent greater at cruising speed and negligible in climbing. These experiments have resulted in the design in which corrugated sheets are used for the wing covering and smooth sheets for the fuselage. The corrugated sheets have an advantage on the wing, as they take the drag stresses and make it possible to eliminate internal diagonal bracing. The smooth skin is more advantageous on the tapered elliptical section of the fuselage, as it can be fitted more readily to the shape and presents no difficulties in streamlining at seams.

Additional Discussion of Wear Tolerances on Gages

(*Concluded from p.* 383)

for all classes of General Motors holes is objectionable in principle because of the increasing clearance between bushing and tool as the latter wears down.

Uniformity in size of new reamers and bushings is not worth the price of sacrificing, in a National standard, some of the primary requirements of a general system of fits referred to in the foregoing. Also, once basic to oversize holes become generally adopted, reamers most suitable to produce these holes will become standard tools in practice, being readily available without extra charge. In fact, one of the important reasons why a general system of fits should be beneficial to all groups lies in its strong influence on the unification of such items as tools and gages. Any departure from the standard by an industrial group reduces these benefits.

On the grounds stated, I believe that basic to oversize holes should be maintained as a fundamental feature of the American standard on fits. Furthermore, there seems to be no good reason why the automotive industry could not satisfactorily use such holes.

News of Section Meetings

(*Continued from p.* 295)

he said, "more real progress and more independence of thought seemed to be appearing than ever before. Great strides have been made in appearance. There is a greater diversity of views than formerly on engineering questions, which indicates a very healthy state of mind."

More Quality for Buyer's Dollar

An outstanding feature of the shows was the amount of quality engineering and construction offered per dollar of the buyer's funds. History repeats itself, said Mr. Roos, and details of construction which first appeared on the higher priced vehicles now flourish in the less than $1,000 group. Eight-cylinder engines are now breaking through into this class in the form of a very good package with a lot of power. The amount of automobile that the public can now purchase for $1,000 or less is almost unbelievable.

Cars on the whole are much more attractive in appearance because of lower lines, much attention being given to streamlining, smoother exteriors and neater handling of sheet metal. Colors are better blended and better harmonized, the greater harmony being apparent also on the inside, with a strong tendency toward simpler upholstery, more whipcord and flat goods and less mohair. This is the natural swing back of the pendulum, as we are receding from a period of ornate interiors and turning to a simplicity which makes for greater economy in production and less expense for the buyer.

This last year in design has seen the effect produced by the unusual and striking radiator treatment introduced by the Cord company, which the speaker said deserves a great deal of credit for the way in which it handled a most difficult construction. The avidity with which the radiator design was seized upon and followed shows that it is recognized as a marked step forward. On the other hand, we are in the midst of a great craze for toaster grids for radiators, which certainly has not aided cooling. Mr. Roos believes these will pass, as do all extreme ideas which serve very little utility.

To Insist on Safety Glass

The inside sun visor was said to be an important and useful improvement that the speaker prophesied will be found on even low-priced cars before long. Laminated glass, he said, is almost universal in windshields and it is certain that the public will demand this on all cars in the near future. Some of the eastern motor-vehicle commissioners admit that considerable pressure will be brought by them to require some kind of safety glass because of the serious injuries and fatalities resulting from broken glass.

The rear end of the car is now receiving attention of the designers, and the path pioneered by Cadillac is being followed. Tire carriers and other attachments are assuming less and less of the "junky" appearance with which we used to be content.

Mr. Roos said that he does not know who the Columbus is who rediscovered the tachometer type of speedometer which is coming back and has the great advantage that one can tell at a glance very close to the speed he is making, so that the driver does not have to look so long to get an accurate reading, which at times may be dangerous.

More Power and Smoothness

One notable trend of the last year was toward more cylinders. In 1929 more than 60 per cent of the models were sixes; in 1930 about the same percentage were eights. Piston displacement has been increased by about 10 cu. in. on the average, the average having been brought up by the marked increases made by certain companies, 15 manufacturers now showing more than 350 cu. in.

The whole question of engine smoothness is absorbing a great deal of attention. One school follows multiplicity of cylinders even up to 16, while others who are not seeking great power are tending more and more to counterweighting the crankshaft and the use of some type of balancer, which now takes the form in some places of a combination of the harmonic and the Lanchester vibration damper. The number of main bearings tends to increase.

Radicalism Is Promising

Nothing he has seen this year, continued Mr. Roos, has started so violent a discussion, such bitter criticism and such enthusiastic endorsement as the trend toward transmission redesign. He thinks this is a healthy state of affairs. He hopes there will be more front-drive cars, that cars will be built with the engines in the rear and that other radical designs that are being talked about will come out, so that we shall get away from the deadening sameness that has been felt. Such a departure from sameness is evident in transmissions. Twenty chassis models have four speeds, 63 show three-speed gearsets, 1 has free-wheeling on all gears, 10 have free-wheeling on high and second, and 10 have syncro-mesh.

One of the most interesting aspects of the advent of free-wheeling has been the sudden and profound reverence exhibited for the engine as a brake, remarked Mr. Roos, who said that he never realized what a marvelously effective brake the automobile has in its engine until he started to talk to other engineers about the matter of free-wheeling. The most interesting fact to him is that, in spite of this reverence, no engineering effort has been devoted to increasing the engine's pumping ability; and he thinks we may have endowed the engine with a lot of braking virtue to which it never was entitled.

Great advances have been made in brake design, with increase in surface area and heat radiation, so that we now have brakes that are adequate. If we increase the area and brake pressures only 7 per cent we can forget the approximately 5 per cent of braking power we used to get from the engine at various speeds. Later, when showing slides of tabulated data of brake action, with and without free-wheeling, Mr. Roos showed that at certain high speeds the braking power of the engine is really a detriment in deceleration.

More Than 250 at Meeting

John A. C. Warner, Secretary and General Manager of the Society, was present and gave the Section members a cordial greeting from headquarters and other Sections.

More than 250 members and friends gathered for the open meeting, and the dinner drew 70 of the old standbys. In the brief business session, Chairman Louis Schwitzer announced the selection by the Governing Board of the following to serve on the Nominating Committee to nominate Section officers for the year of 1931-1932: Chairman, George Freers; Bert Dingley, George H. Kublin, Charles Merz and Herman Winkler. The subject of the March 12 meeting is to be Riding Comfort.

Progress Reviewed at Buffalo

AN EXCEPTIONALLY large gathering of members and guests numbering approximately 150, listened with great interest at the Feb. 3 meeting of the Buffalo Section to the presentation

by Austin M. Wolf of a paper on the Engineering Features Disclosed by the 1931 Automotive Vehicles.

This paper was along the lines and covered much of the information given in Mr. Wolf's paper, Automobile Engineering Progress Disclosed at the Shows, which was published in the S.A.E. JOURNAL for January, 1931, beginning on p. 19. Starting with the engine, it progressed in an orderly way through the chassis and concluded with the body.

Noteworthy trends in engines were said to be an increase in the number of cylinders and in horsepower, leaving only two four-cylinder engines in the full-size-car class; a trend away from peak horsepower at extremely high speeds and toward increased torque at low speeds; quietness of operation, with carbureter-intake silencers and rubber mountings; smoothness of operation, with some decreases in compression ratios; damping of torsional vibration; oil cooling; prevention of over-choking; prevention of vapor lock by protection of the fuel line against heat; and reduction of cooling-fan speed.

In transmissions the most notable development mentioned was free-wheeling, adopted by four companies. Six companies now use the synchro-mesh type, and helical gears are gaining, while internal gears are losing ground.

Faster rear-axle ratios have followed upon increase in engine power, and in the truck field six-wheel developments are going forward and rear-axle designs have been revamped because of the adoption of low-pressure tires.

Passenger-car wheels are still decreasing in size, with the 17-in. size now used by four companies. More than a dozen cars now have drop-center rims. Frames have been stiffened against torsional twisting in a number of cases in a variety of ways.

In bodies the trend continues to be toward reduction of height from the ground without decreasing the headroom. The probable vogue in the near future, according to Mr. Wolf, will be the stream-line body to reduce wind resistance, several models already exemplifying this trend.

The speaker held the interest of his large audience throughout the evening, from 8.30 to 11 p. m., with his review of the many engineering developments and refinements made in motor-vehicles during the last year.

Changes in Engines and Cars

Chicago Section Sees Boxing Bouts and Hears Duesenberg, Snow and Dingley

EXCELLENT food and entertainment characterized the first meeting of the Chicago Section in 1931, which was held in the Hotel Stevens on Jan. 27.

Two young ladies, one an accordionist and the other a contralto, furnished music throughout the dinner, playing and singing numbers requested by the members and guests present. Two amateur boxing bouts were staged at the conclusion of the dinner, the first bout at 135 lb. and the second at 145 lb. There was plenty of action and the diversion from the usual run of entertainment proved generally welcome.

Committee Representatives Elected

Following the dinner, Chairman E. W. Stewart announced that the Section had neglected to elect representatives to the Sections and Meetings Committees of the Society and that as a result he had appointed members who expected to attend the Summer Meeting to act on these two Committees. Approval of this action was unanimously voted.

The Chairman then announced that a Nominating Committee to nominate Section officers for next season should be elected. The following members to serve on this Committee were thereupon nominated and elected:

Theodore Gamble
A. J. McArdle
Benjamin S. Pfeiffer
R. E. Wilkin
H. K. Gandelot

Duesenberg Engine Power Doubled

The first speaker of the evening, Fred S. Duesenberg, vice-president of engineering of Duesenberg, Inc., spoke rather briefly on new developments in the automobile field, referring particularly to his own efforts and those of his associates. Originally specializing on the production of racing engines, the Duesenberg company built its first cars for general public use in the years 1919 and 1920. Many of the parts used in the original engines are interchangeable with those of the newest engines built.

After the recent acquisition of Duesenberg by the Auburn Automobile Co., five experimental engines were built. These had four valves to the cylinder and were bigger and the frame of the chassis was strengthened.

In September, 1929, development work on free-wheeling that had been started in 1926 was resumed and considerable progress along these lines has been made since that time.

Among the improvements in Duesenberg engines is a new head which increased the compression ratio from 5.2:1 to 8.5:1 without severe detonation. The spark-plug location has been brought more to the center of the head and the plugs and valves are effectively water-cooled. The horsepower was practically doubled, the new engine developing approximately 180 hp. at 4200 to 4300 r.p.m. A gain in maximum road speed of 17 to 20 m.p.h., using the same body type and the same gear-ratio, has been accomplished.

Mr. Duesenberg concluded his talk by pointing out the necessity for strict attention on the part of all automotive engineers to detail in engine building, which he said will make engines that already are good, considerably better.

Mr. Martin questioned Mr. Duesenberg as to what kind of gasoline was used when the compression ratio was raised to approximately 8.5:1. Mr. Duesenberg answered that Ethyl gasoline had been used.

Improvements Made on Auburn Car

The second speaker was Herbert C. Snow, chief engineer for the Auburn Automobile Co., who based his talk on the plans followed by his company in bringing out new automobile models. In designing the 1931 model Auburn car, the engineering department realized that five very necessary things must be considered: The car must be made more beautiful and must have greater performance, better riding-qualities, increased quietness and greater reliability. Small models were then made, after which full-size wooden models were completed, on which the visibility, seating and comfort were carefully checked. The radiator was made to assume characteristics of the Cord radiator, which had proved particularly popular, and yet was made to retain Auburn individuality. The sedan models, through engineering design, were lowered 2 in. yet a gain of 1-in. headroom in the interior of the car was also achieved. The radiator was raised to enhance the lines of the car, the front portion being flat and the upper part of the shell V shape.

The tie-rod between the fenders was abandoned and the fender brackets made more rigid to give ample support to the lamps. The cowl was lengthened and the windshield sloped. The cowl is of steel stampings, electrically welded, which gives extreme strength combined with lightness. The doors have been made of steel and are also lighter, yet more rigid.

To lower the car and still gain headroom, the rear-seat pan was dropped below the side rails. A rubber cover,

instead of a metal cover, is used on the pan over the rear axle.

The front springs were underslung on the axle to give clearance, and a deep section—5 in.—of the frame was provided for at the front, with a kick-up. This double-drop frame, incidentally, was completely redesigned and is now extra rigid, reducing body vibration and lengthening body life.

To silence operation, the engine is mounted in rubber and the fan has been slowed down. Additional cooling capacity was put into the radiator core, and the shape of the fan blades is such that a sufficient volume of air for ample cooling passes through the radiator. The exhaust has been silenced by insulating the muffler, which has been provided with a flexible mounting.

A combined synchro-mesh and free-wheeling transmission is now used.

Improvements in the 1931 Cord automobiles include strengthening of the frame, better engine manifolding and carburetion, reduced fan-speed, insulation of the exhaust pipe and muffler, and insulation of the body from heat.

Three New Automotive Engines

In 1930 the Lycoming Mfg. Co., a subsidiary of the Auburn company, developed an eight-cylinder engine for truck work. Three-ton trucks using this engine were said by Mr. Snow to be capable of a speed of 60 m.p.h. A V-12 engine for motorboats was also developed, as was a new nine-cylinder, radial, 210-hp. engine for airplanes. These engines are now used extensively in Stinson planes.

Bert Dingley, of the Stutz Motor Car Co., spoke briefly on his impressions of the 1931 Chicago Automobile Show. His short talk, of a humorous nature, was greatly enjoyed by the members present.

Detroit Section Sponsors a Student Movement

PHIL KENT, Chairman of the Detroit Section, has sponsored a student movement. This activity is designed to meet the special needs of student and junior members of the Society in the Detroit Section territory.

An effort is being made to bring to this student activity an open forum where representatives of industry will appear before the students to discuss or demonstrate engineering principles as applied to industry. Among these representatives will be men of National reputation who will welcome discussion by the students and junior members.

The first meeting for this activity will be held Tuesday, March 3, at the General Motors Research Auditorium through the courtesy of Dr. F. O. Clements. Student groups from all scholastic institutions registering students interested in automotive engineering will be represented.

The activity is fortunate in having secured as speakers for the opening meeting such National figures as William B. Stout, of the Stout Metal Airplane Co., and O. T. Kreusser, of the General Motors Corp.

Mr. Stout and Mr. Kreusser are intensely interested in Society activity and in extending its work for the benefit of students and juniors. They agree that the need is mutual, the Society needing the younger element and the younger element surely needing the Society, and that students and the Society can best be served by efforts on the part of S.A.E. officers to bring before engineering students the mature experience of the Society's industrially-minded older members.

Mr. Kent has appointed Alex Taub, of the Chevrolet Motor Co., as chairman of a committee to carry out the wishes of the Governing Board of Detroit Section on student activities. Mr. Taub will be assisted by Prof. Peter Altman, of the University of Detroit; Robert N. Janeway, consulting engineer, of Detroit; and representatives from each of the student groups in the Detroit Section territory.

It is planned to have three meetings such as the March 3 meeting before the close of the present meeting season. Each meeting will be thoroughly considered in order to assure the presentation of the best available material.

The Student Activity Committee to date has received excellent cooperation from representatives of the schools, as well as from officers and members of the Detroit Section, and feels that the movement will succeed.

Diesel Engines Debated

Hill Describes Types at Cleveland Section Meeting and Discussers Consider Applications

CAN THE High-Speed Diesel Engine Compete with the Gasoline Engine? was the subject of the paper presented at the February meeting of the Cleveland Section by H. D. Hill, vice-president of the Hill Diesel Engine Co., of Lansing, Mich. One hundred and twenty-five Section members and guests gathered at the Hotel Statler for the dinner on Feb. 9 and were joined later by 75 more who came only for the meeting.

After the dinner a short business meeting was held and a committee to nominate candidates for Section officers for the year 1931-1932 was elected as follows: Herbert Sauers, of the Exide Battery Co.; A. A. Skinner, of the Leece-Neville Co.; A. K. Brumbaugh, of the White Motor Co.; W. R. Brown, of the Firestone Tire & Rubber Co.; and W. C. Robbins, of the Gabriel Mfg. Co.

Dale Brown, manager of the Cleveland Better Business Bureau, gave a 10-min. address on the subject, Is Cutting Corners in Business Justified? After a short inspirational talk by General Manager John A. C. Warner, Mr. Hill's paper was presented by the author and a lively discussion followed. Short prepared discussions were read from J. G. Vincent, of the Packard Motor Car Co.; H. C. Dickinson, of the Bureau of Standards; and A. Boor, of the Willys-Overland Co., all of whom were unable to be present. Others joining in the discussion were C. S. Kegerreis, of Toledo, Ohio; Ferdinand Jehle, of the White Motor Co.; Arthur Nutt, of the Curtis Aeroplane & Motor Co.; A. J. Scaife, of the White Motor Co.; O. D. Treiber, of the Hercules Motor Co.; Prof. F. H. Vose, of the Case School of Applied Science; and T. M. Robie of the Fairbanks-Morse Co.

Injection Systems Described

Mr. Hill described the difficulties that the designer has to overcome in trying to develop small high-speed Diesel engines from principles which have been successful in the manufacture of engines of 8-in. or greater bore. A brief description of the direct-injection system, wherein the fuel is injected directly into the cylinder, and the antechamber system, in which the fuel is injected into an antechamber or precombustion chamber, was followed by a detailed description of the type of engine manufactured by the Hill Engine Co. This has an antechamber placed at an angle in the cylinder-head and having a volume equal to about one-half the total clearance space. This is completely water-jacketed and communicates with the cylinder by means of a single large hole in the bottom. Advantages claimed for this design are that a fine fuel spray is not required, high turbulence is easily obtained, little heat is transferred to or from the antechamber outlet, and there is a definite amount of precombustion.

The fuel valve used with this system is of the closed type, having a spring-loaded check-valve opening with the pressure, and a spray button with a single round straight hole about 0.020 in. in diameter. The pump used is of aluminum or cast iron, with inserted steel cylinders and lapped plungers. A port in the side of the cylinder

acts as the inlet valve, admitting fuel at the bottom of the stroke. On the up stroke, this port is covered. At the end of the pressure stroke a groove on the plunger uncovers this port, and the pressure on the fuel is relieved through a hole in the center of the plunger connected with this groove. This positive pressure-release permits the check in the spray valve to close positively and cut off further discharge. Metering is accomplished by a taper pin working in a hole in the end of a plug, each cylinder having its own pin and plug, with the pins all connected so as to work in unison from the engine governor or hand throttle.

Advantages and Fields of Use

The advantage which might be expected from the use of the Diesel engine as a powerplant for a passenger car or truck, as pointed out in the discussion, would arise chiefly from the inexpensive fuel used and the efficiency of the Diesel engine. Also, because of the ability of this engine to accept considerable overloading for a short period, less gearshifting should be necessary on hills or in traffic. In contrast to these advantages, a more expensive engine construction is required; operation is not as smooth, particularly when idling; the fuel cost would not remain low if the demand for this type of fuel were to largely increase; and there is a tendency to give a smoky exhaust.

Marine and aircraft-engine requirements were said to be very similar. The Diesel seems to be well adapted to this type of service and, as these services are expanded, will be used to an even greater extent than at present. The particular advantage that the Diesel offers in air service is, of course, the decrease in fire hazard.

At present Diesel engines do not operate on a true constant-pressure cycle and as time goes on they are approaching operation on the Otto cycle, just as the high-speed high-compression gasoline engines operating on doped fuel are tending to get away from the Otto cycle and approach the constant-pressure cycle. It was pointed out that the engine of the future might be some type intermediate between these two present designs.

Diesel engines for general automotive work may some day be a reality. Difficulties that now exist probably will be overcome but, until then, some discussers expressed belief that their use will be automatically restricted to marine and aeronautic fields.

Correct Lighting Explained at Baltimore

NINETY - THREE members and guests assembled for the February dinner and meeting of the Baltimore Section at the Southern Hotel on Feb. 6. Chairman George O. Pooley presided, and once more the effect of his tireless efforts was shown in the large audience.

The focal point of the meeting was the announcement by Mr. Pooley of the recognition of the Baltimore Secton as an official Section of the parent Society. In making this known to the assemblage, the Chairman read the following letter from General Manager John A. C. Warner:

> At the Jan. 8 meeting of our Council, the application of the Baltimore Section to be removed from its probationary status and recognized as an official Section of the Society was discussed, and the Council unanimously approved your request.
>
> Many favorable comments were heard regarding the progressive spirit that exists among the members of your Section, and it was felt that your record amply justifies the granting of the Section status to you.

Considerable feeling was aroused by the personality injected by a complimentary footnote addressed to Chairman Pooley in Mr. Warner's handwriting, reading:

> You fellows are certainly doing a fine job in Baltimore! Hope I can repeat my visit some time soon. I enjoyed every minute of my stay with the Baltimore gang.

The speaker of the evening was W. M. Johnson, commercial engineer of the General Electric Co., from Cleveland, who addressed the gathering on the subject, Driving at Night.

Puts Punch in Lighting Talk

Avoidance of extremes is always a wise course to pursue, yet it is difficult to prosaically describe Mr. Johnson's address. From the very beginning it was fraught with a "punch." The lecturer knew this subject of proper lighting and illustrated his views and developments both by word parallels and lantern slides.

A striking instance of what proper lighting of highways will accomplish is found in the experiments made on St. Clair Avenue, Cleveland. Before the installation of the new lights, fatal accidents averaged six per year on this highway. The new lighting system has reduced this figure to an average of two. Other cases similar to this were presented merely as illustrative of why the General Electric Co., in cooperation with other organizations, feels it necessary to devote time and money to the development of correct lighting.

Continuing his address, Mr. Johnson said, "We have found it takes approximately 10 years from the time a new idea is conceived before it becomes commonplace to the public. Improvements in lighting are not as dramatic as the more universal mechanical developments, hence they do not penetrate public consciousness as quickly."

The second half of Mr. Johnson's talk was most interesting, as in this portion, by means of equipment brought from Cleveland, he dissected light for the benefit of the audience, separating a ray of light into thousands of particles that compose the beam. His versatility produced many a laugh, as did the effect of some of the early head-lamp lenses which were developed to eliminate glare.

The speaker attributed the strides made by his company to the fact that "we work from the motor-vehicle operator's standpoint, to produce for him better and more satisfactory lighting effects and not solely to eliminate glare." At the close of the talk the meeting was turned into an open forum, the speaker answering the questions of various members.

A Nominating Committee composed of Villor P. Williams, G. H. MacCauley, C. A. Gunther, C. H. Bandel and W. B. Robe was appointed to present names of candidates for Section offices for the ensuing term.

Fire Apparatus Considered at Los Angeles

HOW important a part engineering and mechanics play in modern fire-fighting was revealed to 100 members of the Southern California Section at the Alexandria Hotel in Los Angeles on Feb. 6. Several papers and impromptu talks on motor fire-apparatus were given, and a jazz band rendered some hot rhythm as theme music for the program. Three types of apparatus were discussed: rural, county and metropolitan.

At a short business session preceding the technical part of the evening Chairman F. C. Patton called for the selection of a Nominating Committee to choose nominees for Section officers for next season, and the members of the Committee were elected.

Chief Scott, of the Los Angeles Fire Department, was called upon to make some remarks prefacing the scheduled program. He spoke of the reliance of professional fire-fighters upon the engineers who design the equipment, and was emphatic in urging the makers of fire apparatus to continue to increase the hair-spring responsiveness of the units. As a sidelight, the fire chief brought out the fact that, strange as it may seem, fire trucks are subject to a speed limit. The vehicles are so heavy and traffic phases so uncertain that it is necessary to require drivers to keep within certain safe rates of travel. In conclusion, he complimented the assembled engineers on their unceasing efforts to produce more perfect mechanisms with which the peacetime soldiers in the fire department can protect life and property.

Severe Service Requirements

The first scheduled speaker, Prof. J. F. Fairbank, of the Davis Agricultural College, delivered his paper on rural fire-fighting equipment in an ex-

tremely interesting manner, outlining the mechanical problems that confront non-urban firemen but leaving the answering of the problems to the engineers. Versatility required of rural fire-apparatus was especially stressed. He impressed upon those representatives of fire-equipment companies who were present that a great market exists for rural units and that a great deal of research is needed to improve the pieces in use today. A collection of lantern slides depicting rural apparatus in use throughout the State was shown.

Chief Johnson, of the Los Angeles County Fire Department, was next introduced and spoke briefly on some of the subjects covered by Professor Fairbank.

W. E. Powelsen, master mechanic of the Los Angeles County Fire Department, the second speaker on the program, described the various methods of testing equipment and outlined some of the extreme stresses to which some of the department's units are subjected. He said that fire apparatus is replaced in 15 years; not from wear, but because of obsolescence, and concluded with a comment upon the cooperation between automotive engineers and fire-department officials, which is growing more effective each year.

W. P. Akers, of the Seagrave Co., took the floor next and discoursed on metropolitan fire-trucks. Most of his remarks were on the triple-combination unit: hose wagon, chemical carrier and straight pumper. This type of vehicle, he asserted, is highly efficient in combatting everything from small fires to major conflagrations. He used slides to depict the engineering features of the three-purpose piece.

At the close of the scheduled talks, several visitors were introduced, including J. W. Mountain, Los Angeles County shop superintendent; J. J. Hunt and W. E. Sadring, of Engine Company 18, Los Angeles County Fire Department; Fred and W. W. Hirsch, of the Seagrave Co.; J. E. Buie, of the Mack Truck Co.; and Theodore Hobgood, assistant general sales manager of the Moreland Motor Truck Co.

The meeting was finally thrown open to discussion and, in answer to a question as to the longest period of continuous operation his equipment has been subjected to, Mr. Powelsen replied "52 hours." This test was occasioned by the Santa Fe Springs oil-well fire.

Kansas City Section To Be Organized

ON JAN. 26 a group of S.A.E. members met in Kansas City at dinner to consider the organization of a Section with its headquarters in that city. This has been under consideration for some time as the result of requests from members in that territory for some local activity of the Society.

Officers were elected to serve for the remainder of the Section year so that the work of getting the Section under way might be properly organized. R. H. Van Ness, of the City Ice Co., of Kansas City, was elected Chairman; James A. Edwards, of the Jesco Lubricants Co., Vice-Chairman; C. W. Whipple, of the Allison Airplane Co., Secretary; and Orville Gilbert, of the Gilbert Automotive Co., Treasurer.

As in the case of other Sections, it was decided to hold monthly meetings, preceded by a dinner.

A second meeting was held on Feb. 16, the arrangements for the program having been made by J. A. Edwards, who was appointed Chairman of the Program Committee, working in conjunction with the Section officers.

At the next Council meeting formal request will be made for the recognition of this Kansas City group as a probationary Section.

Laws Impede Development

Buckendale Tells Philadelphians How Unreasonable Restrictions Affect Truck and Coach Design

DEVELOPMENT of motor-trucks and motorcoaches and their most economical use are being hampered by State laws that are unreasonably restrictive. The influence of such legislation and the technical difficulties which confront the designer because of it constituted the subject matter of a very interesting paper by L. R. Buckendale presented before the Philadelphia Section at its Feb. 11 meeting. The title of the paper was Motor-Truck and Bus Axles and their Carrying Capacities as Limited by State Laws.

As pointed out by Mr. Buckendale, the tire must be recognized as the fundamental starting point in a proposed design of vehicle, and many of the difficulties occasioned by legal limitations are tied up in tire sizes. The author traced the development of the tire from its first form, the iron tire, to its present stage, the balloon or low-pressure tire. All the developments had three aims: longer life, greater carrying capacity and greater cushioning effect. Each of these developments demanded increased tire size and, with it, increasing vehicle width to accommodate not only the larger tires but the larger size of other parts of the vehicle which was made necessary by increased speeds, loads and so forth. Because roads were narrow, the increasing truck size attracted the attention of legislatures, and a series of limitations on over-all width, length and weight appeared. Possibly such laws served a useful purpose a number of years ago, but today they are very seriously hampering the designer in his endeavor to provide a more effective vehicle and are working a real hardship according to Mr. Buckendale, not only on the truck and coach manufacturers, but on all users of trucks, for the latter are not able to obtain the advantages of vehicles that are possible from the manufacturing standpoint but prohibited by out-grown legislation.

Mr. Buckendale illustrated in detail with lantern slides how the legal restrictions force manufacturers to adopt constructions that cannot be regarded as good design. The paper was essentially the same as the one presented by the author at the Summer Meeting of the Society last year, which was printed in the S.A.E. JOURNAL for July, p. 24.

Concerted Opposition Imperative

The six-wheel vehicle is offering some relief, Mr. Buckendale stated, but this is practically nullified by the fact that greater gross loads are permitted for the six-wheel vehicle and, as advantage is taken of this, the dual-tire arrangement is still required.

Another phase of the legislation tangle is the fact that laws of the several States are very much at variance as to width limitations and gross weights. Similar lack of agreement is true of lengths of single vehicles and of trailer combinations. A manufacturer who is selling in a Nation-wide market cannot take advantage of the more reasonable restrictions of some of the States, for his product would be barred in others.

In conclusion, Mr. Buckendale pointed out the need of the help, cooperation and influence of everyone interested in motor-truck manufacture and use, through properly organized associations, in modifying existing legislation which is hampering development of more satisfactory equipment and to prevent future legislation that will be equally harmful.

The danger of future legislation was sharply emphasized during the discussion by the statement that two States not far distant from Pennsylvania are considering legislation that will be very detrimental to the motor-truck industry. This legislation is not being fathered by the farmers or the passenger-car owners, but by the railroads in an endeavor to limit the movement

of freight by trucks. One State is proposing to reduce the allowable gross load from 22,000 to 14,000 lb. The second State referred to, while continuing the 22,000-lb. gross load, is considering limiting the length of a single vehicle to 26 ft., and of a train of vehicles to 45 ft. In addition, if this legislation passes, the maximum speed of all vehicles of over 2-ton capacity will be limited to 15 m.p.h.

In view of the importance of this subject, a short business session was injected into the meeting to consider ways and means by which the Section as a unit can take official recognition of the matter and possibly formulate a plan of attack on harmful legislation.

Canadian Section Meetings

Industry's Attitude Toward Workmen and Engineers' Mental Quirks Are Considered

WITH D. R. Grossman, vice-president and general manager of the Studebaker Corp. of Canada, Ltd., as speaker and John A. C. Warner, Secretary of the Society, as a guest, the Canadian Section was doubly favored at its meeting in Toronto on Feb. 18. The Firestone company acted as unofficial host for the evening and distributed its tire ash trays to all present. Announcement was made that seven or eight other societies, including the Buffalo Section of the S.A.E., had been invited to the March meeting, at which C. F. Kettering is to speak.

Among the guests present was W. G. Robertson, secretary of the Canadian Automobile Association and general manager of the Ontario Motor League. Mr. Robertson drew attention to a bill introduced in the Ontario Legislature to require motor-cars to come to a full stop at all railroad crossings, and the meeting unanimously voted against the proposal.

Mr. Warner made a brief address in which he said that during his recent travels he had seen tangible evidence of improved business. The steel men and accessory and automobile dealers have a more cheerful outlook than at any time since the market crash. He said that there is a present need in the automotive industry for ideas, constructive thinking and originality. The engineer now has an opportunity to make a mark in his own organization such as he never enjoyed in the past. Managements are more receptive at the present time toward new ideas than they have ever been. "I wonder," he concluded, "if some of us are taking full opportunity of the possibilities lying within our grasp, in our own organizations, to gain ideas from those under or associated with us?"

Human Factor in Industry

Mr. Grossman gave a very thoughtful address dealing with the human factor in industry. Until recently, he said, management recognized only two factors in industrial operation. These were money and material. Labor was regarded as a commodity and treated accordingly. That is greatly changed now, although much remains to be done. There is still the lack of a definitely known plan that will assure a reasonable income and reasonable conditions for the worker. "I believe," he remarked, "that the solution of the larger problem of depressions lies largely in the solution of the numerous lesser problems which seem more nearly within our reach."

In conclusion, Mr. Grossman said that the automotive industry had experienced a phenomenal growth but it is possible that this growth had been due more to the natural desire for ownership of the product than to methods used by the industry. This desire for ownership will continue, but some adjustments will have to be made.

The following were elected as the Section's Nominating Committee: R. H. Combs, C. E. Tilston, A. Bentley, F. Ponsett and N. Daniels.

Mental Gears the February Subject

At their monthly meeting on Jan. 28, the members turned from the concrete realities and problems of engineering practice to the more intangible complexities of the human mind, when Prof. Yale S. Nathanson, of the department of psychology at the University of Pennsylvania, gave an address on The Mental Gears of Engineers.

Because of the change of date from the third to the fourth Wednesday in the month, not so many members were present as usual, although for the previous four meetings, according to a report by Chairman Alex McArthur, there had been a steady improvement, the attendance being: September, 78; October, 80; November, 89; December, 105.

Professor Nathanson's address, in serio-comic vein, was listened to with a great deal of interest. Mentioning that 25 per cent of engineers leave their calling within 5 years, 43 per cent within 10 years and 57 per cent within 25 years, the speaker said that he thought the reasons for this might be worthy of some study.

Professor Nathanson likened a human being to a cube, with attributes in three dimensions. Under the first head comes social competency, divided into motivation and control. Under the second head—economic—comes intelligence and efficiency. Under the third—educational—comes intellect and discrimination. Some men have strong motivation but lack proper control; others are extremely intelligent but lack efficiency.

Wichita Told about Gluing in Aircraft

A VERY successful meeting of the Wichita Section was held on Feb. 13 in the Aviation Grill of the Allis Hotel, Wichita's newest and finest hostelry. The date was somewhat against the Section, but it proved to be no stumbling block, as this meeting was considered one of the best ever held in Wichita. The speaker was T. R. Truax, of the Wood Preservation Section of the Forest Products Laboratory, Madison, Wis.

The meeting was opened by Vice-Chairman H. Fletcher Brown in the absence of Chairman Al. Mooney, who is out of the city for a few months. After a short reading of minutes and an announcement pertaining to the April meeting, the session was turned over to Mr. Truax, who gave a talk on Gluing of Wood in Aircraft.

The members were soon convinced by the speaker that wood was by no means out of the picture. Designers everywhere are still dependent on wood because of the strength-weight advantages it offers over most metals. Ease of working and the cost of metals serve still more to make the use of wood more or less mandatory. The fact that gluing enables one to use lumber that otherwise would have to be discarded makes plain the fact that wood is considerably cheaper than metal.

Glued joints, according to tests made at the laboratory at Madison, fail almost 100 per cent in the failure of the wood and not in the glue line. This, of course, would not be the case where improper gluing was done. The necessity of a definite glue line was emphasized by Mr. Truax. Consistencies of glues and pressures of glue clamps or presses are the direct cause of failure or of durability of joints. Moisture content of the wood must be correctly held to prevent warping within the glued section. The percentage of moisture will vary, however, with the locality where the part is fabricated.

Roller application is to be favored in preference to brushing, as more even distribution of the glue is brought about by the use of a roller spreader.

Casein glue is the best discovered as yet for airplane construction. Blood-albumen glue is satisfactory but requires heat to set it, therefore making its use of less value than the

casein, which may be used cold. Time of assembly, that is, time between spreading of the glue and application of pressure, is very influential in good gluing operations.

Protection of the glued joint and of the wood after gluing is done is very essential to a durable glue-joint. Mr. Truax stated that the laboratory is working with disinfectants for this purpose, the object being to inhibit the working of micro-organisms that bring about a condition of rot. Fungus growths would therefore be eliminated. In the case of aircraft, however, we are more concerned about moisture absorption than about the organisms. Both will, however, enter into the picture in aviation in a short time. At present our problem is to prevent volume changes in the wood members.

The meeting closed with a long discussion which brought to light many interesting facts and everyone of the 40 present thought that they had learned much.

Meetings of the Society

(*Concluded from p.* 289)

meeting will return gratified with the activities of the week and ready to play the rôle of enthusiast in the future.

The environment at White Sulphur is conducive to the combination of work and play, business and relaxation, that one expects to find at a Summer Meeting. Recent additions to the Greenbrier Hotel and cottages assure comfortable accommodations for all; and the golf courses, tennis courts, swimming pool, clubhouse and other facilities for sports promise a week brimming full of enjoyment.

Program Includes All Activities

Each of the Professional Activities of the Society has asked for representation on the technical program, which consequently will present a cross-section of the Society's varied interests. In addition to the sessions planned by the Professional Activities, there will be a General Session, a Research Session and a Standards Session. The committees responsible for the success of the sessions are arranging for their respective programs, concerning which announcements will be made in succeeding issues of the S.A.E. JOURNAL and in meeting bulletins.

The Meetings Committee, working through a subcommittee appointed at the Annual Meeting, is preparing a recommendation to the Council which is designed to take care of the scheduling of committee meetings so as to cause the least possible conflict with the other activities, whether technical or recreational. Members who have suffered in the past from the overlapping of committee meetings with other events will look forward with much interest to the presentation of this plan, which, it is hoped, will tend to alleviate a situation that has become increasingly acute.

Commemorative Aero Meeting

Curtiss, Vought and Guggenheim Honored in Addresses for Their Work in Advancing Aviation

A DISTINGUISHED gathering of guests and members of the various engineering Societies listened with a great deal of enjoyment to the commemorative speeches extolling the work of the three late leaders in aeronautic progress—Glenn H. Curtiss, Chance M. Vought and Daniel Guggenheim — at the Commemorative Aeronautic Meeting in the Engineering Societies Building Auditorium, Feb. 25. Members of the families and former associates of the three men were present in large numbers occupying special seats which had been set aside for them in the center of the auditorium.

The Presidents of the cooperating Societies or their delegates occupied positions of honor on the platform with the Chairman and the speakers and were introduced by Col. V. E. Clark, the Chairman of the evening. Mr. Roy V. Wright, in his introductory remarks, mentioned other aeronautic leaders deceased in the last two years whose contributions to the industry cannot be overlooked, notable among these being C. M. Manly, whose work with Langley and later in the development of the radial engine brought him lasting fame.

Constructors' Place in History

The early activities of Glenn Curtiss and his work and relations with the United States Navy were admirably covered by Capt. John Towers, assistant chief of the Bureau of Aeronautics of the Navy. Captain Towers was particularly fitted for this task in view of his close association with Mr. Curtiss all through the early days of construction of the various Curtiss ships for the Navy. Mr. Curtiss' major achievements were presented by Frank Russell, until recently vice-president of the Curtiss Airplane & Motor Co.

Chance Vought, who at the time of his death was Vice-President of the Society for Aircraft Engineering, was one of the outstanding successful business men in the aircraft field. The history of his connection with the industry, of his development with it and the many successful results he achieved were described by E. E. Wilson, president of the Sikorsky Aviation Corp. Mr. Wilson, who, as a commander in the United States Navy, came into contact with Mr. Vought and his most recent productions, outlined those factors which in Mr. Vought's life had been his contributions to the art. More than 30 of Mr. Vought's former associates made the trip from Hartford to take part in this meeting and to commemorate the work of the man whose ideas and ideals they are at present endeavoring to carry on.

Aid Given by Daniel Guggenheim

To no one man not taking active participation in the designing or construction in aircraft or aircraft engines is the industry more indebted than to the late Daniel Guggenheim. Through his financial assistance to universities and through the creation of the Guggenheim Foundation for the Promotion of Aeronautics, many aeronautic projects have been given impetus and assistance. The work of many universities in which he was the silent partner is still being carried on and in many instances, had it not been for Mr. Guggenheim's assistance, their presence in this field might not have been possible. Admiral H. I. Cone, for many years a close associate of Mr. Guggenheim, delivered the talk.

Besides the many slides illustrating the addresses, an exhibit of pictures, models, trophies and early products of the three men honored was on view in the lobby of the Engineering Societies Building from Feb. 24 to 28. Many of these photographs, which are of priceless historical value, illustrated the various phases of development through which modern airplanes have passed and are a tribute to the intrepid daring of the men who built and flew them in the early days.

Spring Production Meeting

TWO days, probably May 6 and 7, are to be devoted to a Spring Production Meeting in Milwaukee. This is sponsored by the Milwaukee Section, and the Society is cooperating with the Section in the arrangements for and the conduct of the meeting. The definite dates will be announced later in THE JOURNAL and bulletins.

Tentative plans are for the holding of two technical sessions and a Production Dinner, with local plant-inspection visits on the afternoon of the second day.

Personal Notes of the Members

Lawrance Elected President of Aeronautical Chamber

At a meeting of the Board of Governors of the Aeronautical Chamber of Commerce of America during the annual meeting of the members in New York City on Jan. 29, Charles L. Lawrance was elected president of the Chamber, to succeed Frederick B. Rentschler, who served as president during 1929 and 1930. This is the second time that Mr. Lawrance has been president of the aircraft industry's National trade association, as he filled that office during 1924 and 1925.

Among the vice-presidents elected from the seven geographical divisions of the Chamber are the following members of the S.A.E.: Clayton J. Brukner, president of the Waco Aircraft Co., of Troy, Ohio; E. L. Cord, president of the Auburn Automobile Co., of Auburn, Ind.; P. G. Johnson, president of the Boeing Airplane Co., of Seattle, Wash.; and Harris M. Hanshue, president and general manager of the Western Air Express, Inc., of Los Angeles.

Mr. Lawrance gained his greatest fame as designer of the Wright Whirlwind engine that Lindbergh, Byrd, Chamberlin, Kingsford-Smith and other noted aviators made famous. He was vice-president and later president of the Wright Aeronautical Corp., of Paterson, N. J., from 1923 to September, 1930, when he left that organization and the Curtiss-Wright Corp., of which he was vice-president and a director, to form the Lawrance Engineering & Research Corp., of New York City, of which he is president. He ranks among the earliest members of the S.A.E., having been admitted to Member grade in 1906, his application carrying the progressive number 73. He was born at Lenox, Mass., in 1882, attended the Groton School, at Groton, Mass., for seven years, and was graduated from Yale University with the class of 1905. At the time of applying for membership in the Society, he was engineer for the B. L. M. Motor Car Co., and has been engaged in automobile and aeronautic work ever since, both in this Country and in France, as consulting engineer and in engineering and executive capacities with various companies.

Mr. Lawrance's first direct connection with an aeronautic company was in 1916, when he became consulting engineer and treasurer of the Samuel S. Pierce Aeroplane Corp., of Southampton, Long Island, N. Y. The following year he became president and chief engineer of the Lawrance Aero Engine Corp., of New York City. He remained at the head of his own company for five years and then, in 1923, was elected vice-president of the Wright Aeronautical Corp. Two years later he was elected to the presidency of the Wright organization, to which his patents on the air-cooled engine have been sold. He became vice-president of the Curtiss-Wright Corp., of New York City, in 1929.

In recent years Mr. Lawrance has been an active and prominent figure in the activities of the Society, having been Chairman of the House Committee in 1928, toastmaster at the dinner at the Aeronautic Meeting in St. Louis in February, 1930, and a speaker at other aeronautic meetings. He presented a paper entitled, Air-Cooled Engine Development, at the Annual Meeting in 1922, which was published in THE JOURNAL for February, 1922, p. 135, and in TRANSACTIONS, part 1, 1922, p. 431.

CHARLES L. LAWRANCE

Crouch in New Connection

George F. Crouch, who has been prominent in the Society's marine activities for more than a decade, has announced that he is now connected with the firm of Young & Crouch, of New York City, engaged in the engineering, designing and selling of marine engines and boats.

Mr. Crouch was born in 1878 at Davenport, Iowa, and received his technical education at Webb's Academy of Naval Architecture and Marine Engineering from 1898 to 1901. Upon being graduated from this institution, he became draftsman for the William Cramp & Sons Ship & Engine Building Co., of Philadelphia, and later for Tams Lemoine & Crane, of New York City. In 1905 he returned to his Alma Mater as head of the Department of Naval Architecture. In addition to this work, he accepted, in 1907, the technical editorship of *Motor Boat*, and besides these activities, engaged for a number of years in the designing of motorboats of all sizes.

In 1925, Mr. Crouch became vice-president of the Horace E. Dodge Boat Works, of Detroit, and, five years later, president of George F. Crouch, Inc., of Middletown, Conn.

A member of the Society since 1919, Mr. Crouch served on the Marine Division of the Standards Committee in 1919 and 1920 and on its Motorboat Division in 1921. During 1926 he was Second Vice-President of the Society, representing marine engineering. He has presented two papers, Automotive Applications of Marine Engines in the War, which was printed in the May, 1919, issue of THE JOURNAL, p. 349, and in TRANSACTIONS for 1919, part 1, p. 112; and Engines for Motorboats, which appeared in THE JOURNAL for February, 1924, p. 117.

Miss Earhart's Record Certified

Amelia Earhart was one of eight aviators to whom certificates confirming records established last year were presented by the National Aeronautic Association at a joint meeting of the Association and the Washington Aero Club in the City of Washington on Feb. 3. Senator Hiram Bingham, president of the Association, presented the certificates. The one to Miss Earhart was awarded for establishing a new speed record for women aviators of 181 m.p.h.

Dr. A. E. Becker has been transferred from his post in charge of the fuel and lubrication section of the Standard Oil Development Co., of Elizabeth, N. J., and placed in charge of the knock-testing laboratory of the company at Westfield, N. J.

LeRoy Chadbourne has recently accepted a position with the Eastern Air Transport, Inc., of Brooklyn, N. Y. He formerly was a test engineer for the Wright Aeronautical Corp., of Paterson, N. J.

Hoy Clark was recently transferred from his post as engineer in the Cleveland offices of the Cleveland Wire Spring Co. and is now acting in a sales and engineering capacity on that company's Detroit staff.

Fred Cliffe, a Foreign Member of the

(*Continued on p.* 38)

Applicants for Membership

The applications for membership received between Jan. 15 and Feb. 16, 1931, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AKABANE, SEIICHI, design engineer, Nakajima Aircraft Works, *Tokyo, Japan.*

ANDERSON, W. F., sales engineer, industrial division, Timken Roller Bearing Co., *Canton, Ohio.*

ASH, CARSON W., superintendent of equipment, State Road Commission, *Clarksburg, W. Va.*

AVILEZ, IGNACIO, Jefe del Departamento de Maquinaria, Comision Nacional de Caminos de Mexico, *Carpio, Mexico, D. F.*

BARDWELL, HAROLD F., research engineer, Delco Appliance Corp., *Rochester, N. Y.*

BOEHLY, HENRY W., machine designer, Mergenthaler Linotype Co., *Brooklyn, N. Y.*

BRAUN, W. F. HAROLD, secretary-treasurer, general engineer, part owner, Pennsylvania Lawn Mower Works, *Primos, Pa.*

BROUCK, R. H., special fleet representative, E. I. duPont de Nemours, Inc., *Detroit.*

BROWN, WILLARD C., illuminating engineer, in charge of automotive and aviation lighting, Nela Park Engineering Department, General Electric Co., *Cleveland.*

BROWNE, ANDREW THOMAS, engineer, associated products division, J. G. Brill Co., *Philadelphia.*

BUHL, CHARLES M., body layout, Budd Mfg. Co., *Detroit.*

CHANDLER, N. RAYMOND, general manager for India, Rolls-Royce, Ltd., *Bombay, India.*

CHARLESWORTH, THOMAS RICHARD, Laycock Engineering Co., Ltd., *Sheffield, England.*

CHERON, PIERRE J., art director, Motor Meter Gauge & Equipment Corp., *Toledo.*

CHMEL, JOSEF, technical director and partner, Elektronspol, *Prague, Czechoslovakia.*

COOKE, RUSSELL A., *Dallas, Pa.*

COOPER, EDWIN O., chief mechanic and manager, Pacific Airmotive Corp., *Oakland, Calif.*

COULTER, E. M., mechanic, Equitable Auto Co., *Pittsburgh.*

DALE, FRANK L., general sales manager, National Oil & Supply Co., *Newark, N. J.*

DEAN-AVERNS, REGINALD, chief engineer, Karrier Motors, Ltd., *Huddersfield, England.*

DEAN, W. B., test engineer for Hele-Shaw pumps, American Engineering Co., *Philadelphia.*

DOLL, ALFRED WILLIAM, instructor, Pratt Institute, *Brooklyn, N. Y.*

DUBE, JOHN E., assistant experimental engineer, A C Spark Plug Co., *Flint, Mich.*

ELDERKIN, CLIFFORD L., manager electrical department, Dyson Service, Ltd., *Calgary, Alberta, Canada.*

FAIRCHILD, HAROLD WELCH, assistant aeronautical engineer, United Aircraft & Transport Corp., *Hartford, Conn.*

FICKETT, CALVIN L., superintendent, automotive department, Southworth Machine Co., *Portland, Ore.*

FIEDRICH, GEORGE, designer, Reo Motor Car Corp., *Lansing, Mich.*

FOOTE, GROVER WATERMAN, factory manager, Perfex Radiator Co., *Milwaukee.*

GALE, FERDINAND J., designer, Reo Motor Car Co., *Lansing, Mich.*

GILMER, LOUIS A., mechanical engineer, International Engineering Corp., *Chicago.*

GLEASON, THOMAS C., design and drafting of research and experimental work, American Blower Corp., *Detroit.*

GOETZ, MARTIN G., division lubricating engineer, Pennzoil Co., *Oil City, Pa.*

GRANT, OTIS E., sales engineer, Bohn Aluminum & Brass Corp., *Detroit.*

GROPP, ERNST, manager, Automotive Products Co., G.M.B.H., *Berlin, Germany.*

HAMERLY, F. B., vice-president, Independent Pneumatic Tool Co., *Aurora, Ill.*

HANCOCK, ROBERT H., president, Aircraft Service Co., *Pittsburgh.*

HARPHAM, HORACE, partner, Harpham Brothers, *Toronto, Ont., Canada.*

HARRISON, FRANK G., president and treasurer, Spun Steel Corp., *Canton, Ohio.*

HEISLEY, FREDERICK W., manager, wheel and brake department, Joseph Woodwell Co., *Pittsburgh.*

HENNINGER, ANTHONY A., president and general manager, New Process Gear Co., Inc., *Syracuse, N. Y.*

IAVELLI, TENO, layout man, Timken Detroit Axle Co., *Detroit.*

JACKSON, A. VERNE, district sales manager, The Buda Co., *Harvey, Ill.*

JENNINGS, BRENTON WILLIAM, lubrication engineer, Utah Oil Refining Co., *Salt Lake City, Utah.*

KIMBALL, EARL H., mechanical engineer, John Deere Tractor Co., *Waterloo, Iowa.*

KULIKOFF, NICOLAI ALEX., machine-shop superintendent, Stalingrad Tractorstroi, *Leningrad, U.S.S.R.*

LAFAVE, LAWRENCE V., automotive pattern production, equipment design, pattern foreman, Ferro Machine & Foundry Co., *Cleveland.*

LEJA, ALFRED H., research engineer, A. O. Smith Corp., *Milwaukee.*

LITTLEFIELD, ALTON H., inspector, Quartermaster Corps, Motor Transport, U.S.A., *Camp Holabird, Baltimore.*

LOWE, WILLIAM W., chairman, manufacturing committee, assistant chief technologist, Henry L. Doherty & Co., *New York City.*

MEGARGEE, STANLEIGH, shop superintendent, Corps Area Motor Repair Shops, *Fort Hancock, N. J.*

MIDDLETON, LESLIE HAMILTON, chief engineer, Schwarze Electric Co., *Adrian, Mich.*

MORGAN, WILLIAM C. JR., sales engineer, Oldberg Mfg. Co., *Detroit.*

MUELLER, FRED A., superintendent, Police Department Garage, *St. Louis.*

O'BRIEN, ROBERT L., supervisor of aviation, Commonwealth of Massachusetts, *Boston.*

O'TOOLE, HOWARD M., assistant factory manager, General Motors Truck Corp., *Pontiac, Mich.*

PAWSON, FREDERICK, assistant to technical service engineer, General Motors Products of Canada, Ltd., *Oshawa, Ont., Canada.*

POHL, FREDERIC B., JR., president and chief engineer, Fred B. Pohl, Inc., *Detroit.*

RUSSELL, JOSEPH F., foundry superintendent, Aluminum Co. of America, *Oakland, Calif.*

SAMPLE, GUS H., designer, Busch-Sulzer Bros. Diesel Engine Co., *St. Louis.*

SANFORD, WILLIAM HERMAN, district service manager, The White Co., *Baltimore.*

SHAFFNER, W. L., sales promotion manager, General Motors Electric Sales Corp., *Detroit.*

SHANKS, J. N., master sergeant, Quartermasters Depot, *Camp Holabird, Baltimore.*

SHAW, WALTER R., JR., special representative, Pennsylvania Grade Crude Oil Association, *Oil City, Pa.*

STRATFORD, FRED., president, Fred Stratford, Ltd., *Toronto, Ont., Canada.*

SUCHLA, FRANK J., journeyman machinist, in charge of United States Marine Corps shop, SC 3 A.S., *Managua, Nicaragua.*

TAYLOR, CARL REDVERS, engineer mechanic, Gil Gil Motor Co., *Kenya Colony, British East Africa.*

THOMPSON, J. V., vice-president and general manager, Thompson & Co., *Oakmont, Pa.*

TRYON, WILLIAM A., president, Patent Purchasing Co., *Providence, R. I.*

ULFELDT, JOHN OHR, shop superintendent, The Stoody Co., *Whittier, Calif.*

URFER, ADOLF, chief experimental engineer, Pioneer Instrument Co., *Brooklyn, N. Y.*

WIEBEN, HERMAN C., JR., design draftsman and stress analyst, Keystone Aircraft Corp., *Bristol, Pa.*

WIESER, EUGENE, aeronautical engineer, 69 Ladbroke Grove, *Holland Park, London W. 11, England.*

WINKLER, ALBERT HERMAN, JR., experimental engineer, Bendix-Stromberg Carburetor Co., *South Bend, Ind.*

Notes and Reviews

AIRCRAFT

Present Status of Aircraft Instruments. Technical Report No. 371, prepared by Subcommittee on Instruments. Published by the National Advisory Committee for Aeronautics, City of Washington, January, 1931, 26 pp. [A-1]

The customary classification of instruments is followed in this Report, which contains sections on speed, altitude, navigation, powerplant, oxygen, and fog-flying instruments. The recommendations of the Subcommittee are embodied in the sections on general problems and summary of instrument and research problems. The outstanding problems at present are those relating to navigation in fog and to landing during fog and poor visibility. A satisfactory solution of these problems no doubt will depend largely on the use and development of radio equipment and special instruments. The other research problems outlined in this Report relate mainly to the refinement of existing instruments so as to secure greater accuracy and reliability, which may greatly increase safety during flight.

Strength of Rectangular Flat Plate under Edge Compression. By Louis Schuman and Goldie Back. Technical Report No. 356. Published by the National Advisory Committee for Aeronautics, City of Washington, January, 1931, 24 pp. [A-1]

The materials chosen were those suitable for aircraft construction. The loads were applied in the testing machine until the plate failed to take any more load. The tests show that the loads carried by the plates generally reached a maximum for the 8 or 12-in. width, and there was relatively small drop in load for the greater width. The data obtained will be of use in the design of floats, pontoons, wings and so forth of aircraft when the plating is subjected to pressures against the edges.

Aerodynamic Characteristics of Circular-Arc Airfoils at High Speeds. By L. J. Briggs and H. L. Dryden. Technical Report No. 365. Published by the National Advisory Committee for Aeronautics, City of Washington, January, 1931, 14 pp. [A-1]

The aerodynamic characteristics of eight circular-arc airfoils at various speeds times the speed of sound were determined in an open-jet airstream 2 in. in diameter using models of 1-in. chord. The lower surface of each airfoil was plane; the upper surface was cylindrical.

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

The results indicate that the section of the blades of propellers intended for use at high speeds should be of the circular-arc form for the outer part of the blade and should be changed gradually to the R. A. F. or Clark-Y form as the hub is approached.

The Pressure Distribution Over the Wings and Tail Surfaces of a PW-9 Pursuit Airplane in Flight. By Richard V. Rhode. Technical Report No. 364. Published by the National Advisory Committee for Aeronautics, City of Washington, January, 1931, 103 pp. [A-1]

The investigation comprised simultaneous measurements of pressure at 120 stations distributed over the right upper wing, left lower wing, right horizontal tail surfaces and complete vertical surfaces in one installation and the same number of points distributed over those portions of the wings in the slipstream and the left horizontal tail surfaces in another installation, during a series of level-flight runs, pull-ups, rolls, spins, dives, and inverted flight maneuvers. The results obtained throw light on a number of important questions involving structural design.

The Pressure Distribution Over a Square Wing-Tip on a Biplane in Flight. By Richard V. Rhode and Eugene E. Lundquist. Technical Note No. 360. [A-1]

The Effect of Small Variations in Profile of Airfoils. By Kenneth E. Ward. Technical Note No. 361. [A-1]

Lift and Drag Characteristics of a Cabin Monoplane Determined in Flight. By F. L. Thompson and P. Hp. Keister. Technical Note No. 362. [A-1]

The foregoing Technical Notes were issued during January, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Resistance of Plates and Pipes at High Reynolds Numbers. By L. Schiller and R. Hermann. Technical Memorandum No. 600. Translated from *Ingenieur-Archiv*, September, 1930. [A-1]

Wrinkling Phenomena of Thin Flat Plates Subjected to Shear Stresses. By F. Bollenrath. Technical Memorandum No. 601. Translated from *Luftfahrtforschung*, vol. VI, no. 1, Dec. 12, 1929. [A-1]

Wrinkling Reinforced Plates Subjected to Shear Stresses. By Edgar Seydel. Technical Memorandum No. 602. Translated from Jahrbuch 1930 der Deutschen Versuchsanstalt für Luftfahrt e.V., Berlin-Adlershof Verlag von R. Oldenbourg, München-Berlin, 1930. [A-1]

Clerget 100-Hp. Heavy-Oil Engine. By Pierre Léglise. Technical Memorandum No. 603. Translated from *L'Aeronautique*, November, 1930. [A-1]

The foregoing Technical Memoranda were issued during January, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Airplane-Cabin Engineering. By Pierre Freyss and John F. Hardecker. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [A-1]

The airplane must offer a degree of comfort, convenience and luxury comparable with that of other means of transportation. The aeronautic engineer, assert the authors, should have this in mind from the inception of the structural design, so that a maximum opportunity for eye appeal is assured the decorator.

Uber die Landung von Seeflugzeugen. By Herbert Wagner. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 14, 1931, p. 1. [A-1]

In this theoretical treatment of the landing of seaplanes the author first describes the interaction between water

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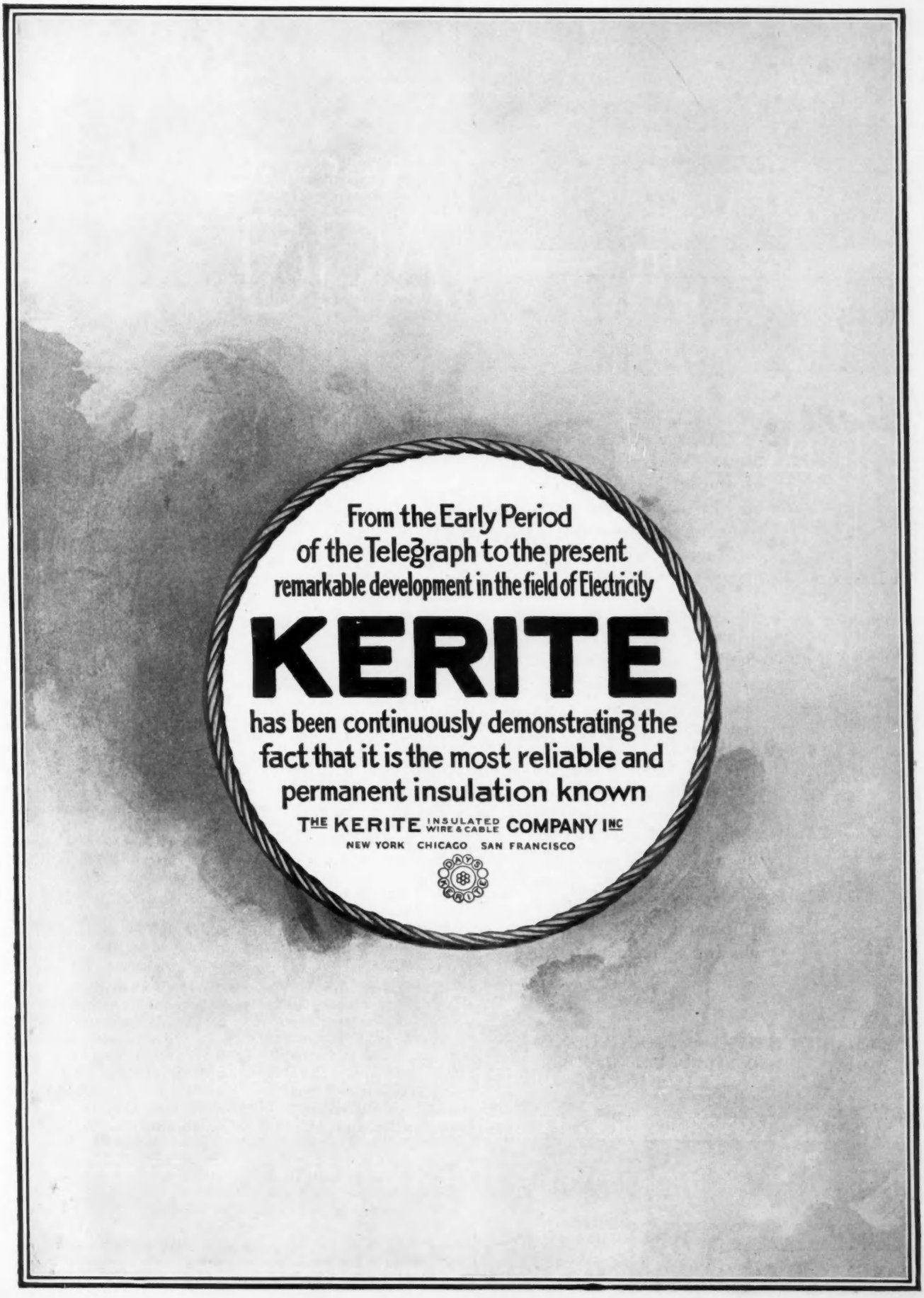
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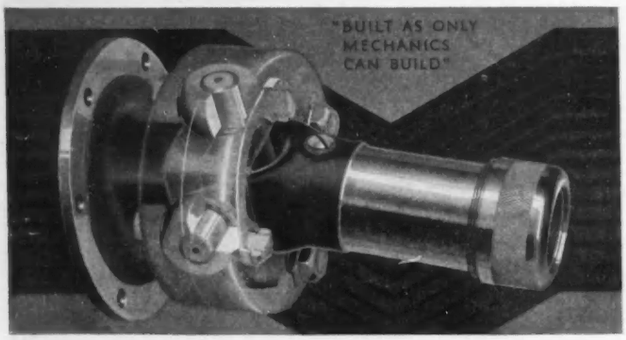

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UNIVERSAL JOINT

Notes and Reviews

Continued

and float in the landing of a keeled float. He compares different types of float and discusses loading effects. The analysis is then extended to factors not so far considered, such as gravity, the effect of float form and depth of immersion on the length of impact surface, the effective keel angle and the elasticity of float construction. Application of the theoretical treatment is made to operation in and taking off from the water, and requisites for practical seaplane design are set forth.

Über den Landestoss von Seeflugzeugen. By Wilhelm Pabst. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt, Jan.* 14, 1931, p. 13. [A-1]

In view of the increasing use of seaplanes, an understanding of the stresses involved in starting from and landing on the water is becoming of more and more pressing importance. Following up an earlier theoretical exposition of the subject, the author in this article treats its experimental and practical aspects.

After briefly summarizing his previous theoretical presentation, he points out that, for the practical employment of the formulas developed, two questions must be answered: What is the elasticity of that part of the structure involved in landing? and What is the length of surface coming into contact with the water and the speed component between it and the water? He points out how these values may be ascertained.

For the experimental investigation, three types of test were considered: measurements on ideal forms, on models and on full-size craft. Tests of the first type, made in Japan, are discussed and the extent to which they support the author's theory shown. For reasons given, model tests were eliminated and a full-size Heinkel HE-9a monoplane was used in the experiments, the objects of which were to test and improve upon the theory developed and to determine the area of the surface brought into impact for different conditions of landing on and operation in water.

The test instruments are described and extensive data given on the experiments, during which stress measurements were made on the float gear and other involved parts of the seaplane as well as on the landing surface of a flying-boat. The results obtained are compared with those arrived at by theoretical calculation and good agreement found, except in the case of the effect of keel shape. Design recommendations and suggestions for further research are made.

Metalluftschiffe. By W. Bleistein. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Dec. 29, 1930, p. 626. [A-1]

For David Schwarz, who completed an aluminum airship in 1897, is claimed the honor of being the pioneer in all-metal lighter-than-air craft. In discussing aluminum as a material for hull construction, the author comments on its weight, its lack of extensibility and its resistance to tearing, the comparison with fabric being unfavorable so far as the first factor is concerned and favorable for the two others.

However, if metal is to be used, the entire system of construction must be suited to its advantageous utilization, and adherence to this principle accounts for the success of the ZMC-2. A description is given of this ship, as well as of the projected MC-25, and the author concludes that a metal airship need not necessarily weigh more than a fabric-covered ship nor cost more to build, while its operation will be less expensive because of its lower air resistance, its ability better to keep its shape, its gas-tightness and resistance to fire and weather damage.

(*Continued on next left-hand page*)

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Notes and Reviews

Continued

The Development of Air Travel. By Stuart A. Hirst. Published in the *Journal of the Institute of Transport*, December, 1930, p. 92. [A-3]

After presenting a brief summary of airplane flight in the last 20 years, the author gives a detailed description of the world's scheduled air routes, municipal airports and night flying in an endeavor to point out how Great Britain has failed in her endeavor to extend air transportation north and west of Croydon, England, so as to connect with various Continental air routes. To remedy this, two routes are proposed: an easterly route from Aberdeen to Edinburgh, Scotland, and from Leeds to London, and a westerly route from Glasgow, Scotland, through Carlile to Manchester, Birmingham and London.

He proposes the utilization of the space over the stations of the London & North Eastern Railway and the London Midland & Scottish Railway by the conversion of the roofs of these stations into one great overhead airdrome and to operate the air traffic in conjunction with the railroad services, as was done in Germany.

Le Service Aéropostal Mixte par Paquebot et Hydravion entre l'Europe et l'Amérique: l'Appareil de Lancement des Hydravions du Paquebot Ile de France. By H. Brillié. Published in *Le Génie Civil*, Jan. 10, 1931, p. 29. [A-4]

One of the fields of modern civilized life in which the airplane has more than justified its existence as a conserver of world power is, according to the figures given in this article, that of transoceanic mail delivery.

Urged on by the demands for quicker communications between Europe and America, the Compagnie Générale Translantique has increased the speed of each new ship launched. At 17 knots, the Bretagne made the crossing in 1886 in 7 days 15 hr. In 1927, the Ile de France, plowing across at 24 knots, cut that time down to 5 days 12 hr. But these speed increases have been costly in power requirements and further increases are likely to prove even more so. Judging by examples of other ships, to enable the Ile de France to gain another day on her crossing by increasing her speed by 4 knots would require virtually a 100-per cent increase in her power.

To gain the extra day for mail delivery by the Ile de France, the company turned to aviation in 1927 and made arrangements for the carrying of a seaplane to be launched from her deck 36 hr. before her scheduled docking. In this article the author describes the seaplanes used and gives the reasons for their choice, the provisions made for the safe lodging of the plane on the deck, the launching means, and security measures such as weather reports, radio communication and landing arrangements.

Oceanic air-mail delivery has advanced in three years from an experiment to an assured routine service. The time saved has been greater than that theoretically calculated; 39 hr. during 1928 and 48 hr. during 1929 and 1930. Further, by demonstrating the safety of a 12-hr. oceanic flight, this type of service paves the way for a complete aerial connection between Europe and America.

Airplane Dopes, Doping, and Dope-Room Requirements. Prepared by Gerald P. Young, Materiel Division, Air Corps. Published by the Chief of the Air Corps, City of Washington, 1930; 19 pp., 15 figs. [A-5]

The aim in this paper is to cover the requirements for doping Air Corps equipment and the installations needed to assure a satisfactory and safe means of producing a lasting finish. The paper is intended more as a guide to securing the correct materials and equipment than as a specification to be followed. The specific requirements for the dopes and other finishing materials, and the process requirements to be followed, are given in Air Corps specifications.

(*Continued on next left-hand page*)

Most automobile prospects this year are from Missouri. They have to be shown. And a half-hour at the wheel of a car equipped with the New Budd All-Steel Body helps show them . . . Helps show them that this car has *balance*—that it holds straight on the road, grips tight on curves. For this body is designed integrally with the chassis. It brings the center of gravity down. Moreover, this body makes the car lighter in weight with increased strength. And it is permanently quiet!

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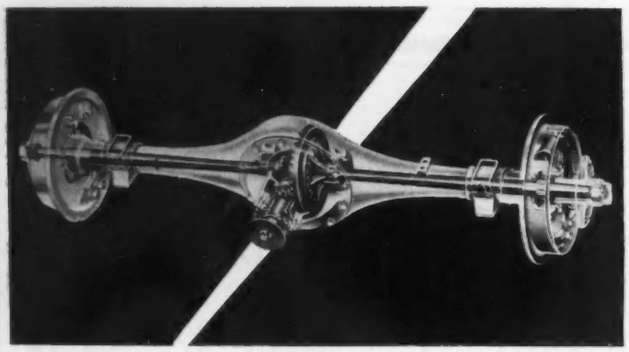

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Notes and Reviews

Continued

Rationalisierung im Flugzeugbau. By M. H. Bauer. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Dec. 29, 1930, p. 630. [A-5]

"Rationalization" in aircraft construction is defined as the introduction of the utmost harmony and coordination in the routine of aircraft factories. A well-ordered smooth flow of operations must be maintained in these undertakings so as to place aircraft building on a plane with other industries in productive efficiency. No matter how excellent the airplane may be, from a technical viewpoint, it cannot become an economic factor so long as its construction involves the expenditure of so much time and money.

Having emphasized the importance of his subject, the author defines its scope, pointing out the elements involved in production, its aim, the means to that end and the requirements of the finished product. He next discusses cost factors, dwelling particularly on wage and accessory charges. Finally, he points out that efficient production does not necessarily mean large-scale production and that the avenue to the desired end is through waste reduction. He discerns three types of waste: that due to the consumer, chiefly the seasonal character of demand and the requirement for a large variety of types; that due to design, involving expensive changes often introduced that do not bring with them a corresponding increase in technical perfection; and that due to production methods. "Less engineering and more production" is the motto suggested for the aircraft industry.

CHASSIS PARTS

Power Transmission Gearing. By Ernest Gregory. Published in *The Proceedings of the Institute of Mechanical Engineers*, London, May, 1930, p. 751. [C-1]

Power-transmission units have been revolutionized during the last 20 years and power capacities are now common that previously would have been regarded as experimental. Transmission gearing may be grouped into four distinct types; namely, speed-reduction gearing, speed-increasing gearing, power gearing, and speed-change gearing.

To meet the demand for maximum efficiency and ever-increasing power capacity in power gearing, designers have had to depart from the generally accepted gear-tooth formulas and to develop special tooth formations to withstand the increasing tooth pressures required, as well as to operate at high pitch-line speeds and to run without undue noise. Additional attention has also had to be given to suitable bearings, case design, forced lubrication, oil-cooling arrangements and many other essential features.

Brakes. Edited by Paul Dumas. Published by the Chilton Class Journal Co., 1931; 124 pp. [C-1]

In this fourth edition of Brakes, the various types, such as Lockheed, Bendix, Steeldraulic, hydrostatic, vacuum and others, are illustrated and discussed. The material is arranged under the headings of Character of Construction, Maintenance, Adjustment of External and Internal Brakes, and Service Notes. A valuable list of equipment needed for thorough brake maintenance is also given.

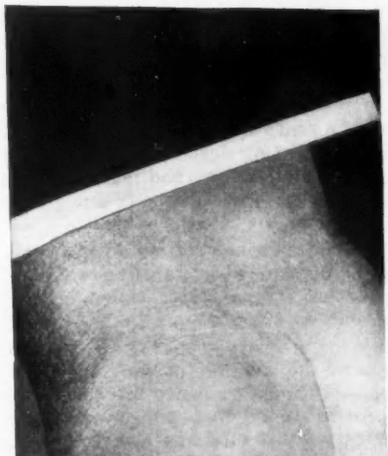
ENGINES

Further Tests on a Two-Stroke-Cycle Oil Engine. By E. A. Allcut. Bulletin No. 7, section 7. Published by the University of Toronto Press; 17 pp. [E-1]

In 1925 Professor Allcut gave the results of a series of tests on a two-stroke oil engine. These results raised many questions. So the author decided to carry on further experiments. These were intended to throw some light on the functioning of the two-stroke cycle in general and on the working of the vertical engine supplied by W. H. Allen & Sons & Co., of Bedford, England, in particular.

(*Continued on next left-hand page*)

This gentleman is holding a handful of selling points



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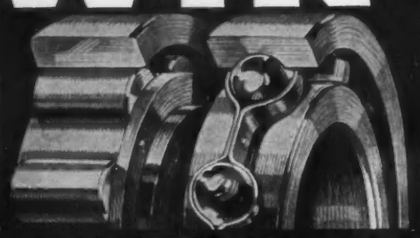
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Notes and Reviews

Continued

One fact brought out by the previous trials was that the chemical composition of samples of exhaust gas obtained by the usual method differed materially from that calculated from the quantities of air and oil put into the cylinder. Tests were conducted by inserting a sampling valve in the exhaust pipe to find out what changes in composition of exhaust gas were occurring during the cycle. Tests were also made to determine the quantity of scavenging air that remains in the cylinder when the exhaust ports are closed by the upward movement of the piston.

The Development and Progress of the Aero Engine. By H. R. Ricardo, F.R.S. Published in *The Journal of The Royal Aeronautical Society*, December, 1930, p. 1000. [E-1]

During the World War, the aeronautic engine underwent a period of intensive development to which was devoted all the best talent of the countries concerned, together with unlimited resources of every kind. Since then progress has been steady; for the last 10 years it has taken the form of improving and consolidating existing design, and there have been few startling developments. Today the modern aeronautic engine is not only about the most efficient prime mover in existence but is one of the most reliable.

Since the war the trend of design has settled down to two highly-developed types of poppet-valve gasoline engines: the air-cooled radial and the V-type water-cooled engine, both of which have approached the extreme limit of their capabilities.

During the last 12 years the average power output of aeronautic engines of given cylinder capacity has increased by about 40 per cent. An all-round increase of nearly 20 per cent in the mean effective pressure has been attained, in part by detail improvement in valve design and operation, in part by the use of a higher compression-ratio rendered possible by improvements in the fuel, resulting from better knowledge of the behavior of their several constituents, and in part by improved knowledge of combustion-chamber design. There has been an all-round increase of more than 20 per cent in the rotational speed, brought about by improvements in materials, in mechanical design and in the technique of manufacture; and, lastly, there has been an improvement of well over 100 per cent in the life of the engine between overhauls, brought about by extensive experience and meticulous attention to detail.

Throughout the whole life history of the four-cycle internal-combustion engine, the author asserts, the exhaust valve has been the weakest chain in the link.

Improvement of aeronautic engines of the present generally accepted type may be attacked from three angles; namely, increase of efficiency, increase of speed, and supercharging. The best hope of reducing weight lies in the application of supercharging, not only as an altitude correction but to give an all-round increase in power.

The intensive research of the last few years on heavy-oil engines has thrown fresh light on certain of the problems connected with gasoline engines, particularly as regards fuel distribution to the several cylinders.

Mr. Ricardo feels that the compression-ignition engine is admirably fitted to work on a two-stroke cycle and therefore sees no fundamental reason why a two-cycle heavy-oil engine should not be developed, the weight of which would approach very nearly that of a contemporary gasoline engine of the same power output.

Pressure Fluctuations in a Common-Rail Fuel-Injection System. By A. M. Rothrock. Technical Report No. 363. Published by National Advisory Committee for Aeronautics, City of Washington, 1930, 16 pp. [E-1]

The tests reported herein were conducted at the Langley Memorial Aeronautical Laboratory, Langley Field, Va., to

(*Continued on next left-hand page*)

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Notes and Reviews

Continued

determine experimentally the instantaneous pressures at the discharge orifice of a common-rail fuel-injection valve, and also to determine the methods by which the pressure fluctuations could be controlled.

The instantaneous pressures at the discharge orifice of a common-rail injection system were determined by analyzing the stem-lift records of an automatic injection valve. The fuel injection was obtained by releasing fuel from a reservoir under high pressure by means of a cam-operated timing valve. The period of injection was controlled by the opening of a cam-operated bypass valve which reduced the fuel pressure between the timing valve and the injection valve. An injection system of this type assures the same rate of fuel discharge regardless of engine speed. The results show that pressure-wave phenomena occur between the high-pressure reservoir and the discharge orifice, but that these pressure waves can be controlled so as to be advantageous to the injection of the fuel. The results also give data applicable to the design of such an injection system for a high-speed compression-ignition engine.

La Carburation et son Interdépendance avec Certains Organes de la Voiture. By Maurice Goudard. Published in *Journal de la Société des Ingénieurs de l'Automobile*, December, 1930, p. 1186. **[E-1]**

No less than 72 different points of contact between the carbureter and other organs and functions of the automobile are mentioned by the author in this article. He makes a plea for cooperation between the carbureter designer and the general automotive engineer, and with this purpose eschews detailed descriptions of the design and functioning of carbureters and points out those factors that influence carburetion efficiency for which the carbureter is not responsible and over which it has no control.

He divides his discourse into six phases of carbureter operation: its installation, engine starting, deceleration, acceleration, full speed, and fuel consumption. Perhaps his most prolific field of investigation is that of engine starting, for he here discerns 26 points totally unconnected with the carbureter itself that the carbureter engineer must check when called upon to explain why his product does not provide quick starting. Not only the parts commonly considered in this connection, such as induction manifolds, heating devices and valves, are brought into the discussion, but the reaction of more remotely related parts, such as brakes, clutch and steering-gear is proved.

Aircraft Diesel-Engine Fuels. By W. H. Graves. Published in the Proceedings of the 11th annual meeting of the American Petroleum Institute, December, 1930, section III, p. 53. **[E-4]**

In this paper the author describes briefly the fuel system of the Packard Diesel aircraft engine and how it differs from the Otto-cycle or gasoline engine. He also describes the properties of the fuel oil that are essential and non-essential to the engine, and briefly touches on the relation of gravity, viscosity, flash-point, autogenous ignition temperature, pour-point, distillation, sulphur, and ash to the proper operation of the engine.

MATERIAL

Detonation as Affected by Mineral Lubricating Oils. By R. O. King, M.A.Sc., and H. Moss, D.Sc. Published in *Engineering*, Jan. 2, 1931. **[G-1]**

The experimenters found that the detonation-inducing actions of vegetable oils, mineral oils, and oleine and oleic acid differed remarkably and varied with the substance used to increase the antiknock property of the original fuel.

Reviewing the experimental results, it was found that the oils differ measurably in effect on ethyl fluid. The detonation-inducing effect was greatest with the asphaltic-

(Continued on next left-hand page)

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Notes and Reviews

Continued

base oil, being represented by a fall of 0.75 compression-ratio for 12 per cent of oil in fuel-oil mixtures. The action of the oils on undoped fuel mixtures of high antiknock value differs from that of the same oils on doped fuels.

Tendency to detonation in the usual conditions of engine operation appears to depend chiefly on the nature and proportion of the paraffins in the fuels, and those having a naturally high-antiknock value possess this property by virtue of a considerable naphthenic content, since aromatics when found in natural fuels generally are in only small proportion.

The deleterious effect of mineral oils on the antiknock value of blended but undoped fuels becomes evident only at high compression-ratios and its magnitude depends mainly on this factor and on the quantity of oil distributed throughout the fuel during combustion.

When lubricating oil is distributed throughout doped fuel during combustion, the deleterious action of the oil is effective mainly on the metallic-dope content, and the action is most striking when the metal is an active catalyst such as nickel and the oil used is an active poison with respect to the metal catalyst.

Lubrication Research Activities—Fifth Report of A.S.M.E. Special Research Committee on Lubrication. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [G-1]

A new general program for experimental work and publications recently formulated by the Committee is outlined in this report and is followed by a brief statement of results already accomplished. Particular attention has been given to the coordination of data obtained by various investigators on viscosity under high pressure, to the study of pressure distribution in the oil film as applied to both thrust bearings and journal bearings, and to the development of methods for measuring oiliness. The report concludes with a brief review of recent European investigations.

On Problems in the Theory of Fluid-Film Lubrication, with an Experimental Method of Solution. By Albert Kingsbury. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [G-1]

The paper describes methods by which fairly accurate solutions of any stated cases can be obtained experimentally, through the analogy between electrical potential and current flow in a conductor and pressure and volume flow in the lubricating film. Solutions are given for a number of cases of plain bearing surfaces and journal bearings, showing close agreement with analytical solutions in cases where the latter have been obtained.

Action of Antioxygens in the Oxidation of Unsaturated Fatty Oils, II. By Bunnosuke Yamaguchi. Report No. 65 of the Aeronautical Research Institute, Tokyo Imperial University, November, 1930, 18 pp. [G-1]

In a previous investigation, Report No. 61, the author studied the antioxygenic action of α-napthylamine and unsymmetrical diphenylhydrazine in the oxidation of olive oil and has ascertained the actual rate of oxidation of the oil in the presence of α-napthylamine. This paper describes the results of investigations on the antioxygenic action of diphenylamine, diphenylguanidine and hydroquinone in the oxidation of olive oil. The results of experiments can be well explained by the theory of mechanism of inhibition which has been developed in the earlier paper. A modified equation has been established in order to calculate the form of the velocity curve for the case of diphenylamine, and it has been shown that the theory agrees satisfactorily with the actual results of experiment.

(*Continued on second left-hand page*)

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Notes and Reviews

Continued

The Determination of Aromatic Unsaturated and Naphthene Hydrocarbons in Light Oils and Motor Spirits. By A. B. Manning and F. M. E. Shepherd. Fuel Research Technical Paper No. 28, Department of Scientific and Industrial Research. Published under the authority of His Majesty's Stationery Office, London, 1930, 14 pp. Price, 16 cents. [G-1]

This paper deals with one part of the investigation in progress at the Fuel Research Station into the composition of the products formed during the carbonization of coal. It deals with the analysis of light oils and motor spirit. Details of typical methods used in previous investigations for the analysis of light oil and the difficulties encountered are discussed. The method described for determining the unsatured and aromatic hydrocarbon and the naphthenes of the cyclohexane series in volatile hydrocarbon-oil mixtures is a chemical method. It involves the separation and weighing of definite derivatives of the aromatic and naphthene hydrocarbons.

Wood in Aircraft Construction. By George W. Thayer. Published by the National Lumber Manufacturers Association, City of Washington, 1930, 276 pp. [G-1]

Much essential technical information regarding the use of wood in aircraft is made readily accessible. Information concerning the supplies of wood that have been used, or are likely to be used, in the construction of aircraft, the annual production of lumber of each species and an estimate of the percentage suitable for aircraft are given.

The book should prove interesting to aeronautical engineers, designers, inspectors and manufacturers of airplanes.

A Study of the So-Called "Over-reduced" Condition in Molten Steel. By J. V. McCrae, R. L. Dowdell and Louis Jordan. Published in the *Bureau of Standards Journal of Research*, November, 1930, p. 1123. [G-1]

A study was made of four heats of acid electric steel for castings in which two heats were in the so-called "over-reduced" state while the others were in the normal condition as made according to general practice. The two types were investigated as regards temperature of the molten metal, structure, and physical and chemical properties.

The lower fluidity or "runability" of the over-reduced steel manifests itself in a short "filming-over time" with the melters' spoon test. This is apparently caused by the rapid formation of silica, which rises from the steel because of the addition of excess metallic silica to an oxidized steel. This phenomenon may also be the cause of incorrect judgment of its temperature, since its emissivity is higher than that of a clean liquid-steel surface.

Machining Properties of Some Cold-Drawn Steels. By O. W. Boston. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [G-1]

Results of a series of machining tests on 13 cold-drawn screw-stock steels and 2 cold-drawn stainless steels are given in this paper. Machinability values for standardized conditions are given for each steel. An attempt is made to correlate the results of these various machining tests with the Brinell, Rockwell and scleroscope hardness values, as well as the analysis and structure of each bar.

Comparative Physical Properties of Chromium-Nickel, Chromium-Manganese and Manganese Steels. By C. L. Clark and A. E. White. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. [G-1]

The steels investigated belong to either the chromium-nickel, the chromium-manganese or the manganese series.

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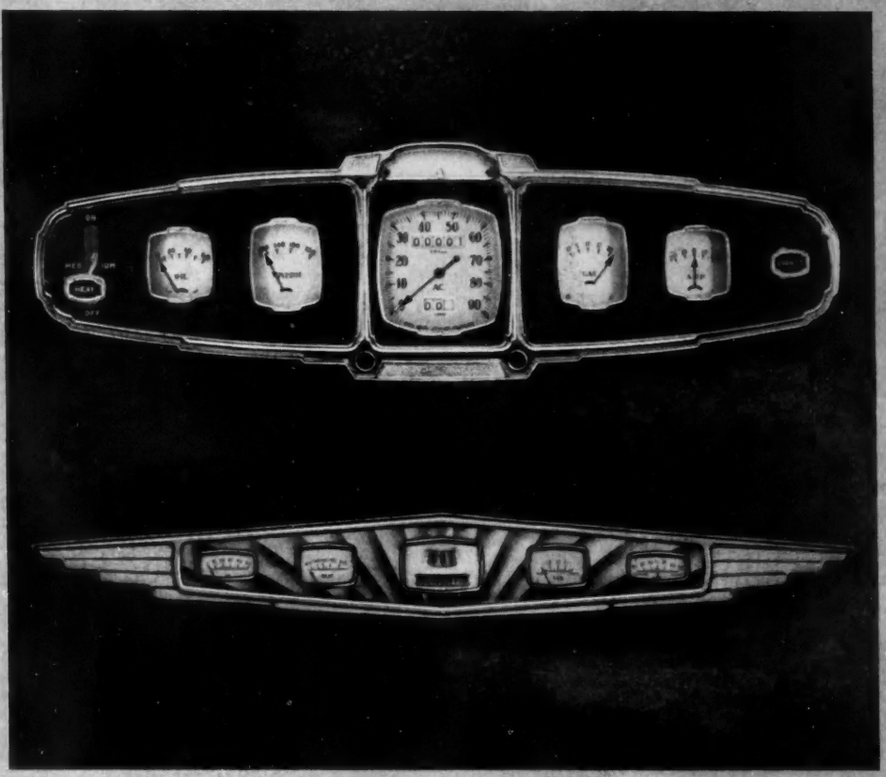

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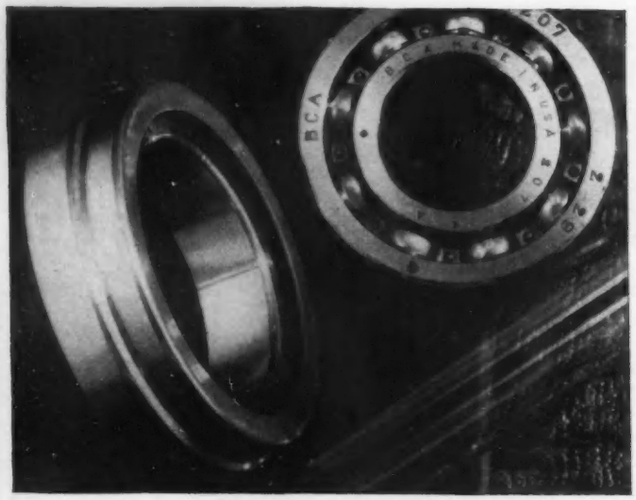

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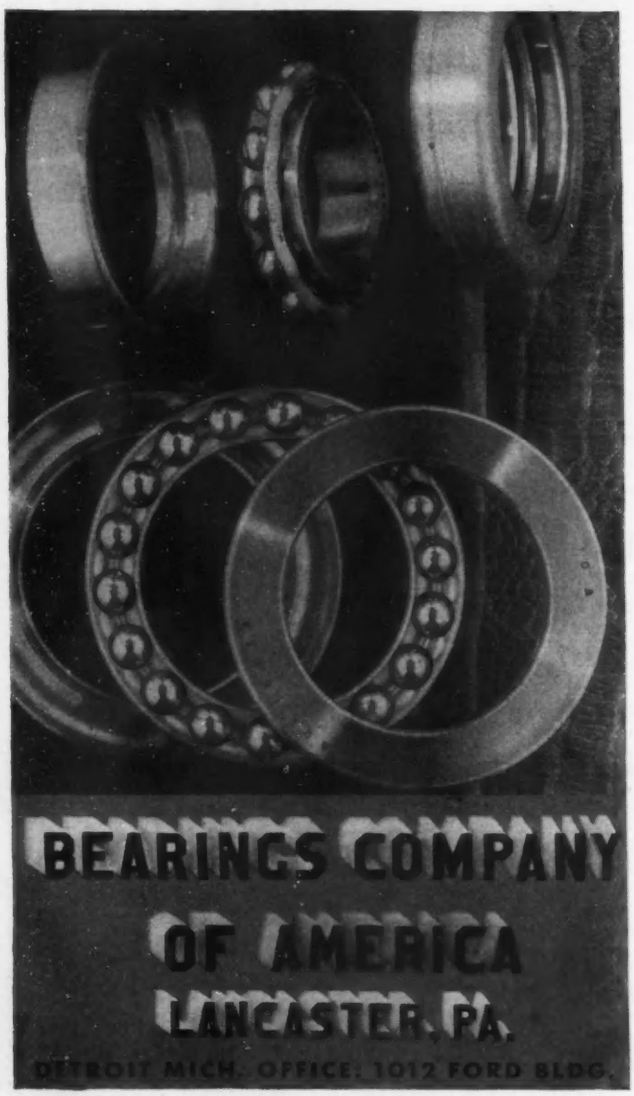

Notes and Reviews

Concluded

The results indicate that the substitution of manganese for nickel in chromium-nickel steels is detrimental, at least insofar as the load-carrying ability of the alloy is concerned. Also that, while the creep resistance of the manganese and manganese-tungsten steels at 1000 deg. fahr. is superior to that of many perlitic steels, it is not equal to that of the Enduro KA2 type of alloy.

Properties of Non-Ferrous Alloys at Elevated Temperatures. By C. L. Clark and A. E. White. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. **[G-1]**

The alloys nickel-copper, nickel-cobalt-titanium, copper-zinc and copper-zinc-tin series were tested at temperatures both above and below their lowest temperature of recrystallization. Results indicate a superiority of the nickel-base alloys over the entire temperature range.

Cemented Tungsten Carbide as Applied to Cutting-Tools. By L. J. St. Clair. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Dec. 1 to 5, 1930. **[G-5]**

Cemented tungsten carbide is a combination of tungsten carbide and metallic cobalt. Measured by the Rockwell A scale, its hardness lies between 87 and 92. Its coefficient of expansion is only one-half of that of invar steel. Its electrical conductivity is low and its compression strength is greater than that of any known material.

It is most economically used as a cutting-edge, therefore cemented-tungsten-carbide blank is attached to a tool shank. Tests have been made of attaching the cemented-tungsten-carbide tip mechanically and by welding, but these have been discarded in favor of the copper-braze, which is the practice generally followed today.

The economic virtues of cemented tungsten carbide as a cutting medium are: great ability to resist abrasion, longer tool life, increased machine-speed, less material wasted in setting up, and greater accuracy throughout a long run.

MISCELLANEOUS

The Secretary's Guide to Correct Modern Usage. By C. O. Sylvester Mawson. Published by Thomas Y. Crowell Co., 213 pp. Price, $2. **[H-1]**

This is a very useful book for all who write, whether they are secretaries or not. Various details of construction, rulings, suggestions, best modern usage and correct typographical styles are made easy for the preparation of copy for the printer.

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A.S.T.M. Tentative Standards 1930. Published by the American Society for Testing Materials, Philadelphia. Price, to non-members, $8.00; to members, $5.50. **[H-1]**

The 1930 edition of the A.S.T.M. Tentative Standards, 864 pp., contains 155 tentative standards. These proposed standards are published for one or more years to elicit criticism before they are formally adopted by the society. They represent the latest thought of the committees on the subjects covered and therefore are finding important application in the various industries. For reference purposes the book should prove most convenient.

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Personal Notes of the Members

(Continued from p. 400)

Society, residing in England, recently accepted a post as designer with Tecalemit, Ltd., of London. His previous position was that of chief engineer with the Laycock Engineering Co., Ltd., of Sheffield, England.

George A. Crosby is now a design engineer for the Supersteam Products Co., Inc., of Trenton, N. J. Until recently he was occupied in the same capacity with the Brooks Steam Motors, Inc., of Buffalo.

Richard Coulson, a specialist in front-end drives who has been closely associated with the development of the compound roller-chain used in this work, reports that as a consequence of the recent amalgamation of the Coventry Chain Co., of Coventry, England, and Hans Renold, Ltd., he is temporarily severing his connection with the precision-chain industry. Mr. Coulson is a Foreign Member of the Society.

John P. Gaty recently assumed the position of research engineer with the Bound Brook Oil-Less Bearing Co., of Bound Brook, N. J. He previously occupied a similar position with the Hantra Co., of New York City.

M. O. Griffith is now employed by the Stanwood Corp., of Covington, Ky., as a test engineer. He was formerly chief engineer of powerplants with the Crosley Aircraft Co., of Cincinnati.

E. E. Harrington has entered the service of the Mack-International Truck Co., of Allentown, Pa. His previous post was as planning engineer and cost estimator with the Eastman Kodak Co., of Rochester, N. Y.

Albert S. Heinrich is now identified with the Bendix Research Corp., of East Orange, N. J. Until recently he was chief engineer with the Aeromarine Klemm Corp., of Keyport, N. J.

Clarence A. Hubert is serving the newly-organized DeVaux-Hall Motors Corp., of Grand Rapids, Mich., as engineer. He previously was automotive engineer for the Hall-Scott Motor Car Co., of Berkeley, Calif.

R. K. Hubbard, formerly of the Royal Army Service Corps, of London, England, has retired from the British Army and taken up an appointment with the Central Argentine Railway as deputy stores superintendent. He is located at Rosario de Santa Fe, Argentina.

At a stockholders and directors meeting of the Monarch Governor Co., of Detroit, on Jan. 28, **R. Hufford** was elected second vice-president of the company in charge of engineering. He had been serving in the capacity of general manager of the company.

Venuswami Iyengar has resigned the position he was holding as assistant superintendent of the motor section of the Government Industrial Institute at Madura, India, and has become engineer in charge of the workshop of R. Patel & Co., of Madras, India.

C. C. Lawton has been transferred from his post as service manager with the Worcester Buick Co., of Worcester, Mass., to the Springfield Buick Co., of Springfield, Mass.

Louis A. Lyzenga is now at work as a private experimental and production engineer in Detroit. He formerly was employed by the Hudson Motor Car Co., of Detroit, as a tool designer.

J. W. Mills recently joined Humber, Ltd., of Coventry, England, after having resigned as a director of the Kelsey-Hayes Wheel Co., Ltd., of London, England.

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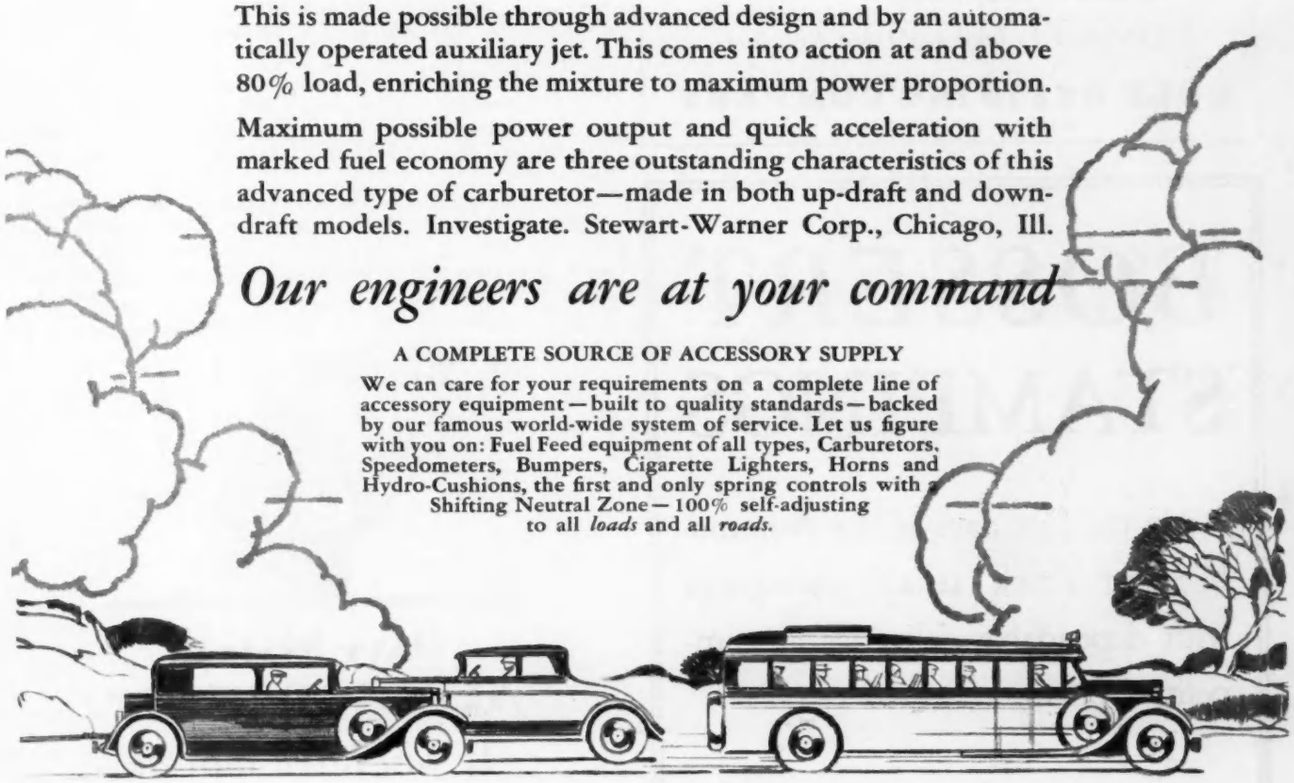

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Personal Notes of the Members

Concluded

W. S. Pritchard is now located with the Detroit Aircraft Corp., of Detroit, which he is serving as factory manager. He previously occupied the position of experimental engineer with the Motor Products Corp., also of Detroit.

Herbert H. Rice recently formed a connection with the Max Brook Co., Inc., of Detroit, having resigned as assistant to the president of the General Motors Corp. of Detroit.

S. Edward Rowe has assumed the duties of engine and chassis engineer with the Stutz Motor Car Co. of America, Inc., of Indianapolis. Prior to accepting this post he was assistant chief engineer of the Marmon Motor Car Co., also of Indianapolis.

Frank A. Schotters has been appointed sales manager and director of engineering for the Luce Mfg. Co., of Lansing, Mich. He formerly was vice-president of the Plymouth Body Works, of Plymouth, Ind.

Floyd B. Selensky has been promoted from the engineering department of the John Deere Tractor Co., of Waterloo, Iowa, to the post of chief draftsman in the company's new-design department.

A. R. Weigel has relinquished the presidency of the Barnard & Leas Mfg. Co., of Moline, Ill., and is now engaged in consulting engineering work in the independent field.

John R. White has been appointed sales manager for Scott Welded Products, Inc., of Long Island City, N. Y. He previously was superintendent of the motor-vehicle department of the Standard Oil Co. of New York, in New York City.

Walter F. Whiteman is now connected with the Gabriel Co., of Cleveland, in the design and research division. Before accepting this position he was employed by the Motor Rim Manufacturers Co., of Cleveland, as a riding-quality engineer.

Harry E. Zuck has been engaged as an experimental engineer with the Lycoming Mfg. Co., of Williamsport, Pa. He was formerly an assistant investigator in the department of engineering research at the University of Michigan, Ann Arbor, Mich.

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